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Trigger Efficiencies for High E_T Electrons

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Abstract

We study the efficiency of the high E_T central electron trigger, `ELECTRON_CENTRAL_18`, for electrons passing "baseline cuts." We find that the track trigger efficiencies are independent of p_T for tracks with $p_T > 10$ GeV/c, but dependent on detector η. The average tracking efficiencies are measured to be $(96.06 \pm 0.11)\%$ to $(98.74 \pm 0.10)\%$ at Level-1 depending on the `XFT` requirements, $(99.88 \pm 0.01)\%$ at Level-2 and $(99.16 \pm 0.08)\%$ to $(99.86 \pm 0.02)\%$ at Level-3 depending on the `XFT` track requirements and Level-3 tracking algorithms. The Level-2 calorimeter trigger is fully efficient at $E_T \simeq 30$ GeV. Since we expect the Level-1 and 3 calorimeter triggers are fully efficient, based on a previous study, those efficiencies are not measured in this document.

1 Introduction

The high E_T central electron trigger, `ELECTRON_CENTRAL_18`, is one of the primary triggers for $W^\pm \to e\nu$, $Z^0 \to e^+e^-$, and $t\bar{t}$ where one or both of the $W^\pm$ bosons decay to $e\nu$. This document presents studies of its efficiency for data taken between March 2002 and August 2004. These data have been reprocessed with the `5.1.0` version of Production and ntupled with the top group's `5.3.3` offline prescription. The studies were done for eight run periods, three before the January 2003 shutdown corresponding to different `XFT` requirements [1], a fourth after that shutdown corresponding to different Level-3 tracking, a fifth and a sixth corresponding to data taken up to February 2004 and a seventh corresponding to runs after the COT aging problem [2], the last corresponding to runs after 200 ppm O_2 gas addition to COT.

Section 2 describes the triggers used for high E_T electrons. The measurements of the tracking trigger efficiencies in different periods are described in section 3, and the measurements of the calorimeter trigger efficiencies are discussed in section 4. Section 5 summarizes and concludes the studies.

2 Trigger Definitions

The requirements for the `ELECTRON_CENTRAL_18` path are

1. `L1_CEM8_PT8` for Level-1

   - It requires a single trigger tower be found in the central region of the calorimeter with `EM` $E_T \geq 8$ GeV, `Had/EM` ≤ 0.125 (this requirement has no effect for towers with $E_T < 14$ GeV) and an `XFT` track pointing to that tower. The `XFT` tracks must have at least 10 (or 11) hits in at least 3 (or 4) layers and momentum $p_T \geq 8.34$ GeV/c.

2. `L2_CEM16_PT8` for Level-2

   - It requires the `L1_CEM8_PT8` trigger at Level-1 and the presence of a central cluster with `EM` $E_T \geq 16$ GeV and `Had/EM` ≤ 0.125. A track match must also occur between an `XFT` track of momentum $p_T \geq 8.34$ GeV/c and the cluster seed tower.

3. `L3_CEM18_PT9` for Level-3

   - It requires a central `EM` offline cluster with $E_T > 18$ GeV and `Had/EM` $\leq$ 0.125. A COT track with $p_T > 9$ GeV/c must also be matched to the `EM` cluster.
   - In `L3_ELECTRON_CENTRAL_18_v-6` (version used for data after the January 2003 shutdown), several requirements were added to the Level-3 path including $L_{shr} < 0.4$, and `CES`-track matching in Z ($\Delta Z < 8$ cm). Other new features are use of $\cot\theta$ of the COT track (or track Z_0) to calculate the transverse component, instead of $Z = 0$, and use of 3 hadronic towers instead of 2 in the `Had/EM` calculation.

A summary of the requirements for these high E_T electron triggers at Level-1, Level-2 and Level-3 is presented in Table 1 and 2.

The Level-1 track trigger definitions have been changed in order to optimize trigger rates, efficiencies and fake rates as the instantaneous luminosity increases. So far there are three different definitions of Level-1 track triggers for electrons, and we will associate them with Period 1, Period 2 and Period 3. The corresponding run numbers are

- Period 1: For runs before 147869 (July 2002), the Level-1 track triggers require `XFT` tracks with 4 superlayers where a superlayer is required to have at least 10 hits. Runs from 141544 through 147869 are used for the efficiency measurements in this period.

- Period 2: For runs from 148153 through 152629 (Oct. 2002), the Level-1 track triggers require `XFT` tracks with at least 3 superlayers where a superlayer is required to have at least 10 hits. Runs from 148153 through 152625 are used for the efficiency measurements in this period.

Table 1: Requirements for the Level-1, Level-2 and Level-3 triggers used in the high E_T electron trigger path, ELECTRON_CENTRAL_18.

Trigger Name	Requirement	
L1_CEM8_PT8	ET_CENTRAL ≥ 8 GeV HAD_EM_CENTRAL ≤ 0.125 (this Had/EM cut has no effect for ET_CENTRAL > 14 GeV)	
	XFT_PT ≥ 8.34 GeV/c XFT_LAYERS $= 4$ or ≥ 3	
L2_CEM16_PT8	L2_EM_ET ≥ 16 GeV L2_HAD_EM_RATIO ≤ 0.125 DCAS_HIGH_EM_CENTRAL_SEED ≥ 8 GeV DCAS_HIGH_EM_CENTRAL_SHOULDER ≥ 7.5 GeV	
	L2_TRACK_PT ≥ 8.34 GeV/c	
L3_ELECTRON_CENTRAL_18	Before Jan. 2003 Shutdown (Periods 1 - 3)	After Jan. 2003 Shutdown (Periods 4 - 8)
	CalorRegion $= 0$ cenEt > 18 GeV cenHadEm ≤ 0.125 nEmObj ≥ 1	CalorRegion $= 0$ cenEt > 18 GeV cenHadEm ≤ 0.125 nEmObj ≥ 1 lshr $\leq .4$ cenDeltaZ ≤ 8 cm ZVert $= 2$ nTowersHadEm $= 3$
	cenTrackPt ≥ 9.0 GeV/c	

Table 2: Requirements for the XFT tracks for high p_T electron triggers.

Period	hits per superlayer	# of superlayers
1	≥ 10	4
2	≥ 10	≥ 3
3-8	≥ 11	≥ 3

During a period from run 150010 to run 150444, quadrant C ($180° < \phi < 270°$) of COT superlayer 2 had about 4 layers turned off. XFT algorithms assumed these off layers to have hits, so we do not expect any inefficiency due to them. We have therefore included these runs in our trigger efficiency calculations.

- Period 3: For runs from 152630, the Level-1 track triggers require XFT tracks with at least 3 superlayers where a superlayer is required to have at least 11 hits. Runs from 152636 through 156487 are used for the efficiency measurements in this period, corresponding to October 2002 through January 2003.

Many changes occurred during the January 2003 shutdown which could have an effect on the efficiency measurement. For example, the calorimeter ADC-to-MeV conversion factors were updated to reduce the difference between online electron energy and offline corrected electron energy. Also during this time period Level-3 tracking algorithms were changed to fix inefficiencies at high $|\eta|$. Level-3 track triggers use COT tracks produced by the "histogram-linking" (HL) algorithm. These tracks are required to have at least 1 stereo hit and 12 axial hits. Data before the January 2003 shutdown used an HL algorithm based on offline version `4.3` where tracking with a seed superlayer other than 8 was known to be inefficient. Data after the January 2003 shutdown use an HL algorithm based on offline version `4.8.4`. Correspondingly we have chosen to define a fourth run period.

- Period 4: This period corresponds to the data taken after the January 2003 shutdown through May 31, 2003 and completes the data set for the summer 2003 conference results. It contains runs 159603 through 163527. The Level-1 XFT track definition is unchanged from Period 3, and the Level-3 tracking algorithms are updated to be the same as offline version `4.8.4`.

Period 5 and 6, spanning from June 2003 to February 2004, are separated by a change in trigger table which dropped the raw silicon data banks in favor of compressed data banks.

- Period 5: This period corresponds to the data taken from June 1, 2003 through August 19, 2003, just before the trigger table change to drop raw silicon banks. It contains runs 163955 through 167715.

- Period 6: This period corresponds to the data taken from August 19, 2003 to February 2004. It contains runs 167717 through 179099.

Table 3: $W^{\pm} \to e\nu$ candidates for non-silicon and silicon good run lists. The "baseline cuts" described in Table 5 are applied.

	w/o silicon	w/ silicon
Period 1	6098	3009
Period 2	12669	11370
Period 3	25354	21534
Period 4	27885	26567
Period 5	30679	30133
Period 6	32465	29844
Period 7	13734	12526
Period 8	41173	40103

The last two periods correspond to runs after the COT aging problem [2].

- Period 7: This period corresponds to the data taken from February 14, 2004 to June 15, 2004, just after COT aging problem. It contains runs 179105 through 184060.
- Period 8: This period corresponds to the data taken from June 16, 2004 to August 2004, just after 200 ppm O_2 addition to COT. It contains runs 184062 through 186598.

The good run lists without and with silicon for the trigger efficiency measurement are taken from the Data Quality Monitoring good run list version 7.0 [3]. This currently has the effect of removing all runs from 179105-182842 (Feb. 14, 2004 - May 19, 2004).

3 Track Trigger Efficiencies

3.1 Dataset

The $W^{\pm}$ no-track trigger, `W_NOTRACK`, as detailed in Table 4, demands the same calorimeter requirements that are used for the high E_T electron trigger, but does not require tracks associated with the `EM` clusters. Trigger efficiencies associated with tracks (`XFT` and Level-3 tracks) thus can be measured with events coming from the $W^{\pm}$ no-track trigger. We start with events passing the $W^{\pm}$ no-track trigger and a COT good run requirement (`COT_OFFLINE` = 1), and apply offline $W^{\pm} \to e\nu$ selection criteria to them. A $W^{\pm}$ candidate is required to have an electron with $E_T > 25$ GeV, as listed in Table 5, and $\not\!\!E_T$ greater than 25 GeV. We also reject candidates with seed towers in wedge 22 east during Period 1, for which the readout cables were swapped for a short period of time before the June 2002 shutdown. For this study, we use $W^{\pm} \to e\nu$ candidates, shown in Table 3.

Table 4: Requirements for the Level-1, Level-2 and Level-3 triggers used in the $W^{\pm}$ no-track trigger path, W_NOTRACK. Plug electrons are added during the January 2003 shutdown.

Trigger Name	Requirement	
L1_EM8_&_MET15	ET_CENTRAL or ET_PLUG $\geq$ 8 GeV	
	HAD_EM_CENTRAL or HAD_EM_PLUG $\leq$ 0.125	
	MET $\geq$ 15 GeV	
L2_CEM16_L1_MET15	L2_EM_ET $\geq$ 16 GeV	
	L2_HAD_EM_RATIO $\leq$ 0.125	
	DCAS_HIGH_EM_CENTRAL_SEED $\geq$ 8 GeV	
	DCAS_HIGH_EM_CENTRAL_SHOULDER $\geq$ 7.5 GeV	
	L1 MET $\geq$ 15 GeV	
L3_W_NOTRACK_MET25	Before Jan. 2003 Shutdown (Period 1 - 3)	After Jan. 2003 Shutdown (Period 4 - 6)
	CalorRegion = 0	CalorRegion = 2
	cenEt > 25 GeV	cenEt > 25 GeV
	cenHadEm $\leq$ 0.125	cenHadEm $\leq$ 0.125
		nTowersHadEm = 3
	nEmObj $\geq$ 1	nEmObj $\geq$ 1
		plugEt $\geq$ 25 GeV
		plugHadEm $\leq$ .125
	MetCut $\geq$ 25 GeV	

The trigger efficiency measurements described in further detail are relative to the offline tracking efficiency for high E_T electrons, which is $(99.3 \pm 0.1)\%$ using offline version 4.11.2 [4].

3.2 Level-1 Tracking Efficiency

The XFT trigger efficiency with $p_T > 8.34$ GeV/c, L1_XFT_PT8, is measured by requiring the L1_CEM8_PT8 bit to be set:

$$\epsilon(\texttt{L1\_XFT\_PT8}) = \frac{\#\text{ of } W^{\pm}\text{ candidates passing }\texttt{L1\_CEM8\_PT8}}{\#\text{ of } W^{\pm}\text{ candidates}}. \tag{1}$$

Since the EM8 bit has already fired in order to satisfy the $W^{\pm}$ no-track trigger and the offline $W^{\pm}$ cuts, measuring the efficiency of the L1_CEM8_PT8 trigger provides the L1_XFT_PT8 efficiency. We find events passing the L1_CEM8_PT8 trigger, shown in Table 6. The derived L1_CEM8_PT8 trigger efficiencies are summarized in Table 7.

We study the dependence of the trigger efficiency on kinematic variables of electrons such as p_T, ϕ, η, and z_0 of tracks. We also study the efficiency for various event conditions, especially those where COT occupancy near the electron track might be high. The variables chosen for this study are

Table 5: Selection criteria of central electrons ("baseline cuts"). Note that the $W^{\pm}$ no-track trigger requires $E_T > 25$ GeV at Level-3.

Electron Variables	Current Baseline Cuts
E_T	> 20 GeV
p_T	> 10 GeV/c
N_{SL}^{axial} with 5 hits	≥ 3
N_{SL}^{stereo} with 5 hits	≥ 2
Fiducial (`FIDELE`)	1 (`CES` X, Z cuts, no Tower 9)
`Had/EM`	$< 0.055 + 0.00045 \times E$
L_{shr}	< 0.2
E/p	< 2 (for $p_T < 50$ GeV)
$\|Z_{vertex}\|$	< 60 cm
$\|\Delta X\|$	$-3.0 < Q_{trk} \cdot \Delta X < 1.5$ cm
$\|\Delta Z\|$	< 3 cm
χ^2_{strip}	< 10

Table 6: $W^{\pm} \rightarrow e\nu$ candidates passing through `L1_CEM8_PT8` trigger. The "baseline cuts" described in Table 5 are applied.

	w/o silicon	w/ silicon
Period 1	5903	2919
Period 2	12510	11228
Period 3	24591	20859
Period 4	26878	25599
Period 5	29472	28948
Period 6	31289	28773
Period 7	13306	12130
Period 8	40440	39387

Table 7: `L1_XFT_PT8` efficiency with $W^{\pm}$ candidates. The "baseline cuts" described in Table 5 are applied to the $W^{\pm}$ electrons.

	w/o silicon	w/ silicon
Period 1	0.9680(23)	0.9701(32)
Period 2	0.9875(10)	0.9872(11)
Period 3	0.9699(11)	0.9687(12)
Period 4	0.9639(11)	0.9636(11)
Period 5	0.9607(11)	0.9607(11)
Period 6	0.9638(10)	0.9641(11)
Period 7	0.9789(15)	0.9784(16)
Period 8	0.9822(7)	0.9821(7)

- Calorimeter isolation with a cone of 0.4
- Track isolation with a cone of 0.4
- # of jets with $E_T^{jet} > 10$ GeV and $|\eta_{jet}| < 1.2$
- $H_T = E_T^e + E_T^\nu$ ($\not\!\!E_T$) + ΣE_T^{jet}, where $E_T^{jet} > 10$ GeV and $|\eta_{jet}| < 2.5$

These studies are shown in Table 8, 9, 10 and 11 and in Figures 1, 2, 3, 4, 5, 6, 7 and 8 using runs in Periods 3, 4, 5 and 7, respectively.

We do not observe any dependence for E_T, ϕ and H_T. within statistical uncertainties. Near $\eta \sim 0$ a significant inefficiency occurs for tracks as a result of the COT space bars and charge collection inefficiency due to the shorter particle path length. The η-dependent trigger efficiency is fitted to the following equation:

$$\epsilon(\texttt{L1\_XFT\_PT8}) = \mathrm{A} - \frac{\mathrm{C}}{2\pi\sigma} \cdot \exp\left(-\frac{\eta^2}{2\sigma^2}\right). \tag{2}$$

Figure 9 and 10 shows the fit results and Table 12 lists the values for A, C and σ. It is clear that the XFT efficiency decreases as a function of time, beginning sometime during Period 4. This decrease in efficiency is presumed to be the effect of decreased charge collection efficiency reported by the COT operations group. To correct for this time-dependent inefficiency, end-users should weight the values in Table 7 for their own luminosity profile. Figure 11 shows the tracking efficiency of a function of detector η and track Z_0. The inefficiency is due to wire center support in COT [5]. This wire center support causes dependence of track Z_0 to the tracking efficiency. Figure 12 shows the tracking efficiency as a function of Isolation ratio and calorimeter isolation. The isolation ratio is defined as

$$Isol. = \frac{Isol^{cal}}{E_T^{ele}},$$

where Isol.^{cal} is the calorimeter isolation and E_T^{ele} is the offline electron E_T. Since

Table 8: `L1_XFT_PT8` efficiency for jet multiplicity selection cut with $W^{\pm}$ candidates.

w/o silicon	no jets in $\|\eta_{jet}\| < 1.2$	≥ 1 jets in $\|\eta_{jet}\| < 1.2$
Period 1	0.9676(25)	0.9706(62)
Period 2	0.9870(11)	0.9900(25)
Period 3	0.9694(12)	0.9730(28)
Period 4	0.9634(12)	0.9667(29)
Period 5	0.9592(12)	0.9693(26)
Period 6	0.9625(11)	0.9712(24)
Period 7	0.9683(16)	0.9719(38)
Period 8	0.9816(7)	0.9856(15)

w/ silicon	no jets in $\|\eta_{jet}\| < 1.2$	≥ 1 jets in $\|\eta_{jet}\| < 1.2$
Period 1	0.9704(34)	0.9678(96)
Period 2	0.9869(12)	0.9889(28)
Period 3	0.9678(13)	0.9735(30)
Period 4	0.9632(13)	0.9657(30)
Period 5	0.9593(12)	0.9689(27)
Period 6	0.9629(12)	0.9711(26)
Period 7	0.9679(17)	0.9711(40)
Period 8	0.9816(7)	0.9853(16)

Table 9: L1_XFT_PT8 efficiency for calorimeter isolation selection cut with $W^{\pm}$ candidates.

w/o silicon	Cal. Isol. $<$ 2 GeV	Cal. Isol. $>$ 2 GeV
Period 1	0.9671(24)	0.9778(70)
Period 2	0.9871(11)	0.9906(31)
Period 3	0.9694(11)	0.9739(32)
Period 4	0.9637(12)	0.9657(34)
Period 5	0.9603(11)	0.9639(34)
Period 6	0.9627(11)	0.9730(29)
Period 7	0.9682(16)	0.9733(42)
Period 8	0.9817(7)	0.9853(17)

w/ silicon	Cal. Isol. $<$ 2 GeV	Cal. Isol. $>$ 2 GeV
Period 1	0.9698(34)	0.9729(11)
Period 2	0.9869(12)	0.9894(35)
Period 3	0.9681(13)	0.9736(35)
Period 4	0.9633(12)	0.9661(35)
Period 5	0.9603(12)	0.9641(34)
Period 6	0.9628(12)	0.9749(29)
Period 7	0.9677(17)	0.9735(44)
Period 8	0.9817(7)	0.9849(18)

Table 10: L1_XFT_PT8 efficiency for track isolation selection cut with $W^{\pm}$ candidates.

w/o silicon	Track Isol. < 1 GeV	Track Isol. > 1 GeV
Period 1	0.9672(26)	0.9716(52)
Period 2	0.9871(11)	0.9891(23)
Period 3	0.9686(12)	0.9755(23)
Period 4	0.9633(13)	0.9664(25)
Period 5	0.9587(13)	0.9690(23)
Period 6	0.9617(12)	0.9726(21)
Period 7	0.9683(17)	0.9711(34)
Period 8	0.9818(7)	0.9854(18)

w/ silicon	Track Isol. < 1 GeV	Track Isol. > 1 GeV
Period 1	0.9715(35)	0.9638(85)
Period 2	0.9869(12)	0.9884(25)
Period 3	0.9671(13)	0.9752(25)
Period 4	0.9631(13)	0.9656(26)
Period 5	0.9601(12)	0.9690(23)
Period 6	0.9618(12)	0.9738(22)
Period 7	0.9679(17)	0.9704(36)
Period 8	0.9817(7)	0.9839(15)

Table 11: L1_XFT_PT8 efficiency for H_T selection cut with $W^{\pm}$ candidates.

w/o silicon	$H_T < 100$ GeV	$H_T > 100$ GeV
Period 1	0.9673(25)	0.9734(67)
Period 2	0.9876(11)	0.9865(32)
Period 3	0.9691(12)	0.9757(29)
Period 4	0.9631(12)	0.9695(31)
Period 5	0.9601(12)	0.9648(32)
Period 6	0.9626(11)	0.9723(27)
Period 7	0.9683(16)	0.9726(42)
Period 8	0.9818(7)	0.9840(14)

w/ silicon	$H_T < 100$ GeV	$H_T > 100$ GeV
Period 1	0.9706(34)	0.9658(11)
Period 2	0.9875(11)	0.9849(36)
Period 3	0.9676(13)	0.9763(32)
Period 4	0.9629(12)	0.9682(32)
Period 5	0.9587(13)	0.9649(32)
Period 6	0.9629(12)	0.9730(28)
Period 7	0.9679(18)	0.9721(44)
Period 8	0.9817(7)	0.9852(18)

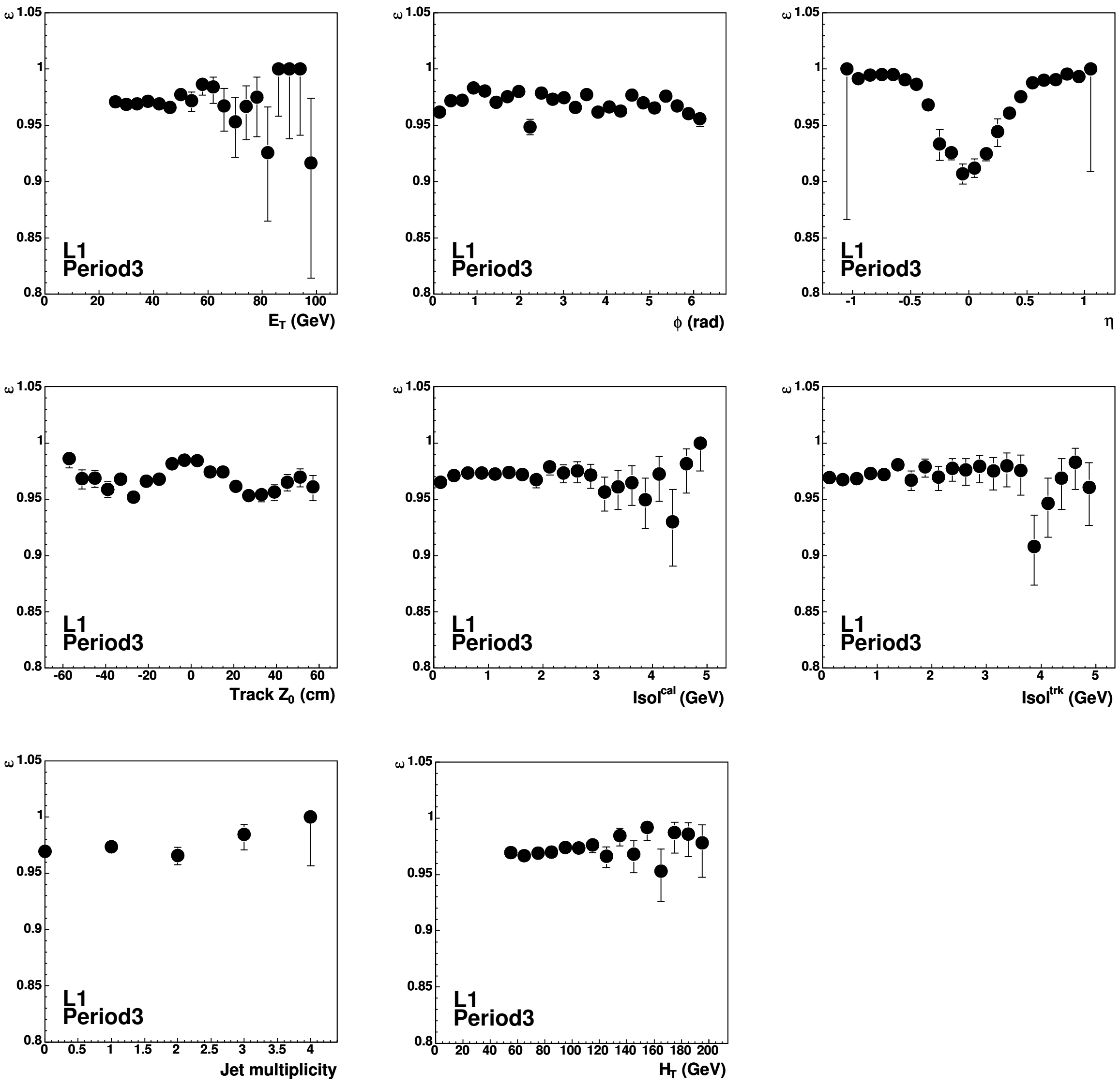


Figure 1: Level-1 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 3 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

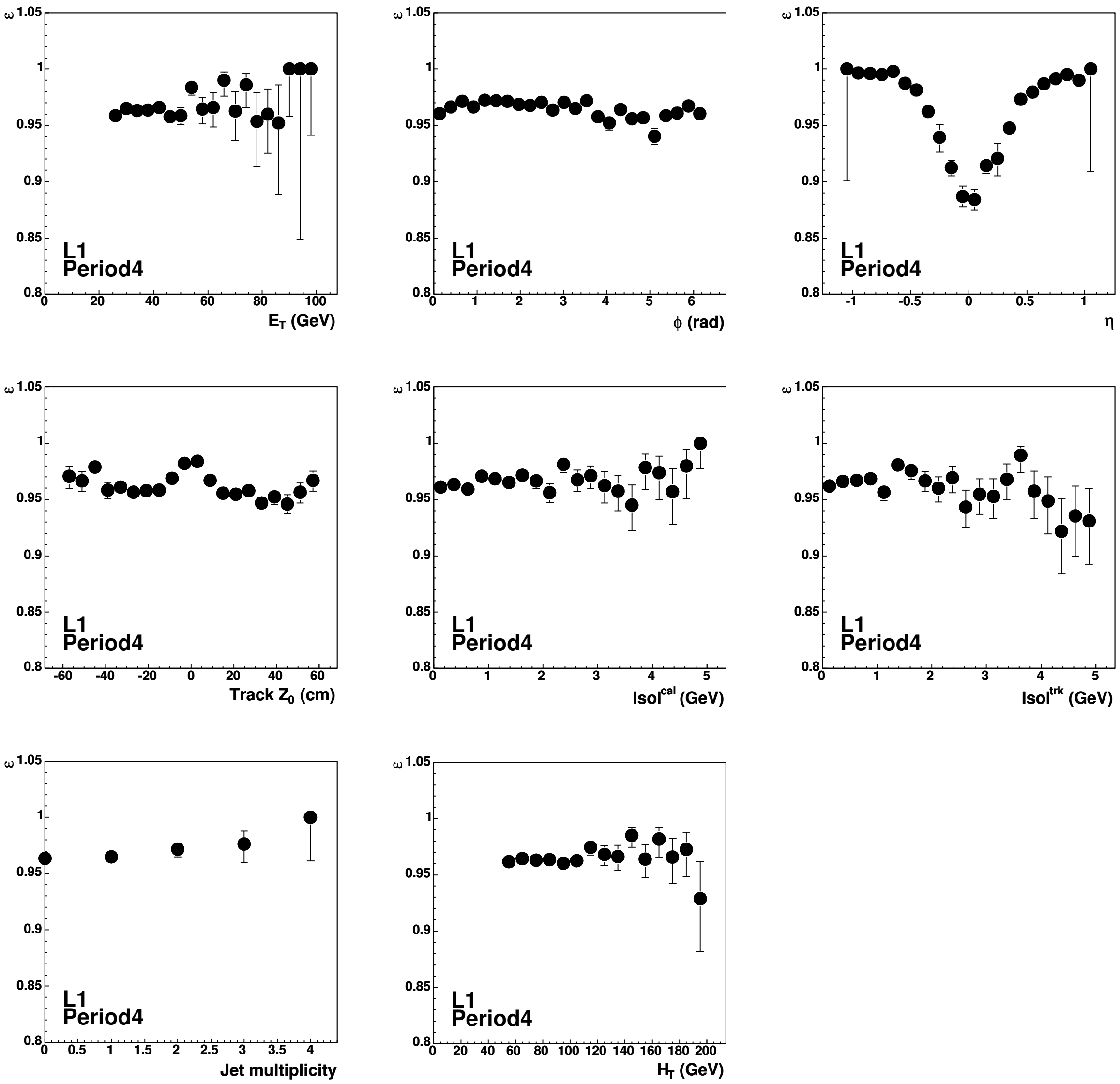


Figure 2: Level-1 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 4 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

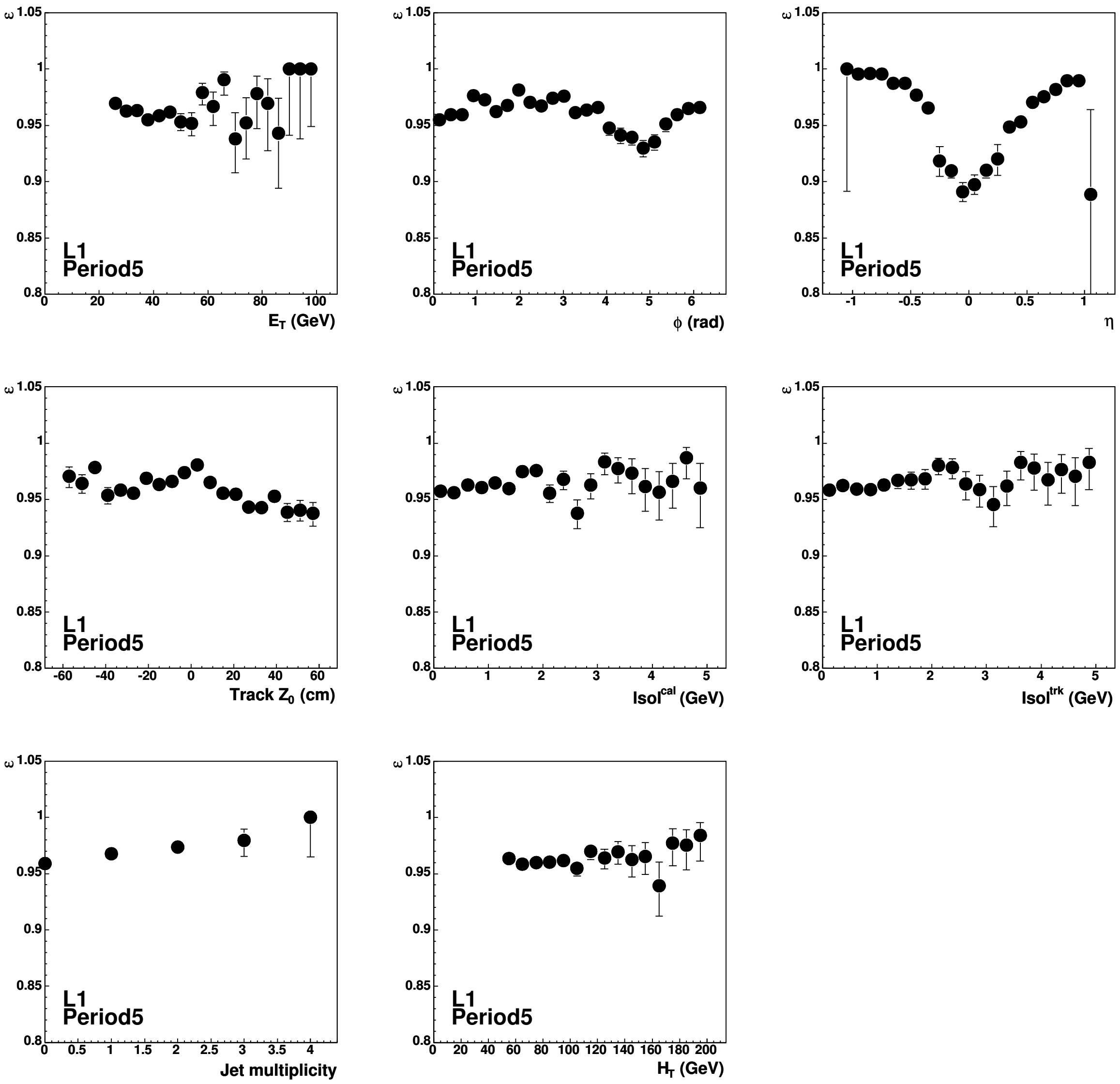


Figure 3: Level-1 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 5 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

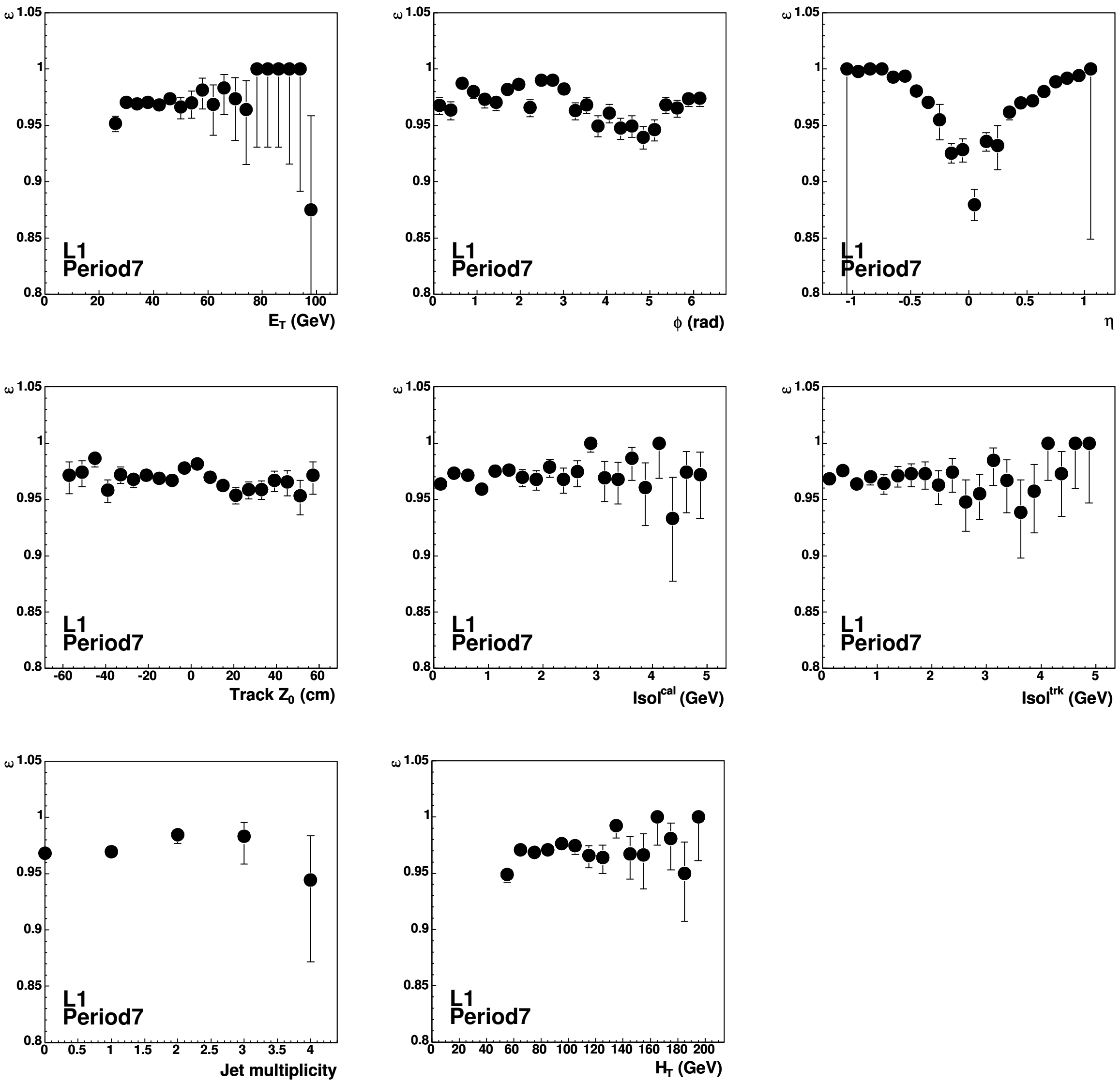


Figure 4: Level-1 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 7 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

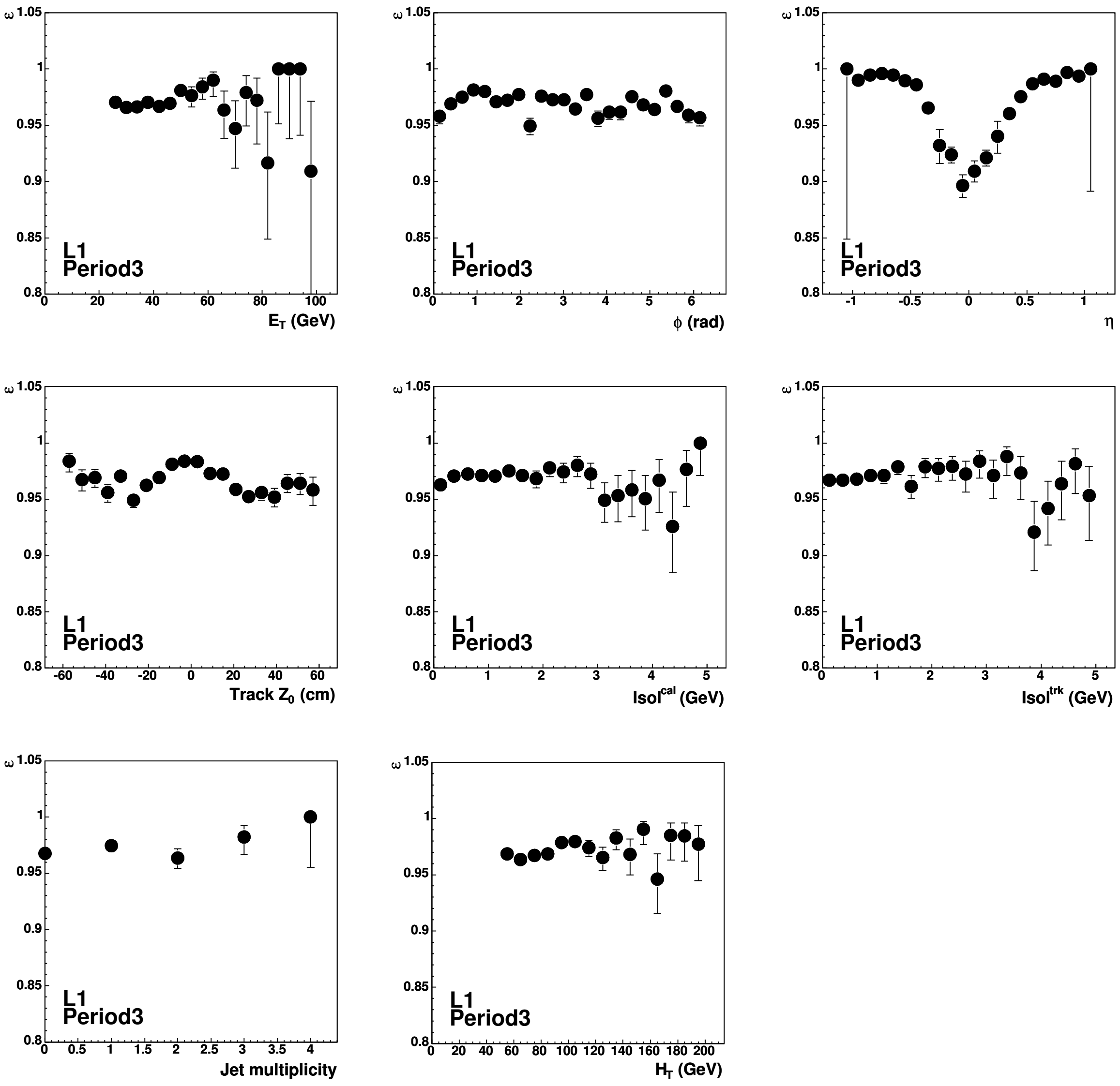


Figure 5: Level-1 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 3 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

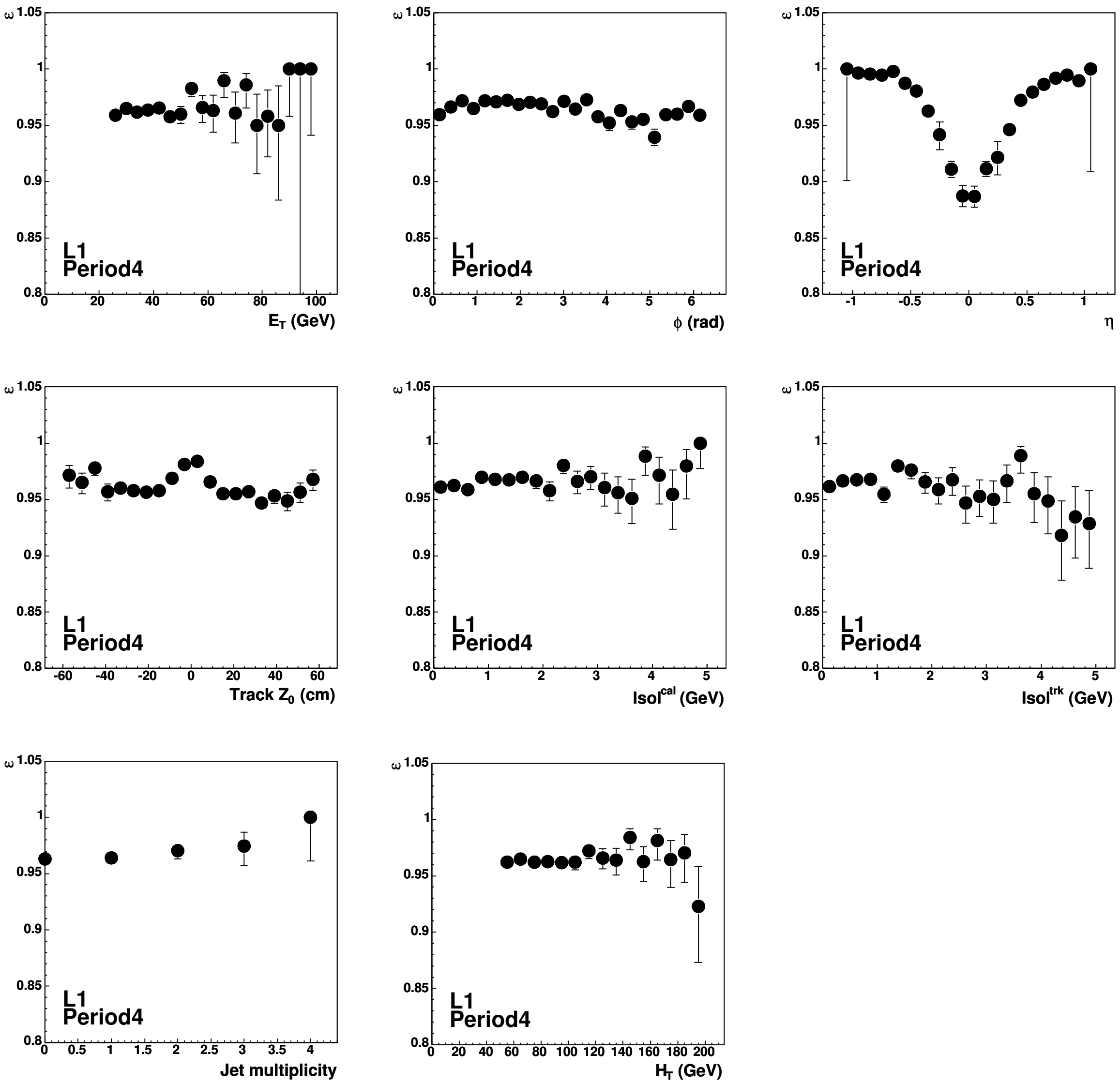


Figure 6: Level-1 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 4 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

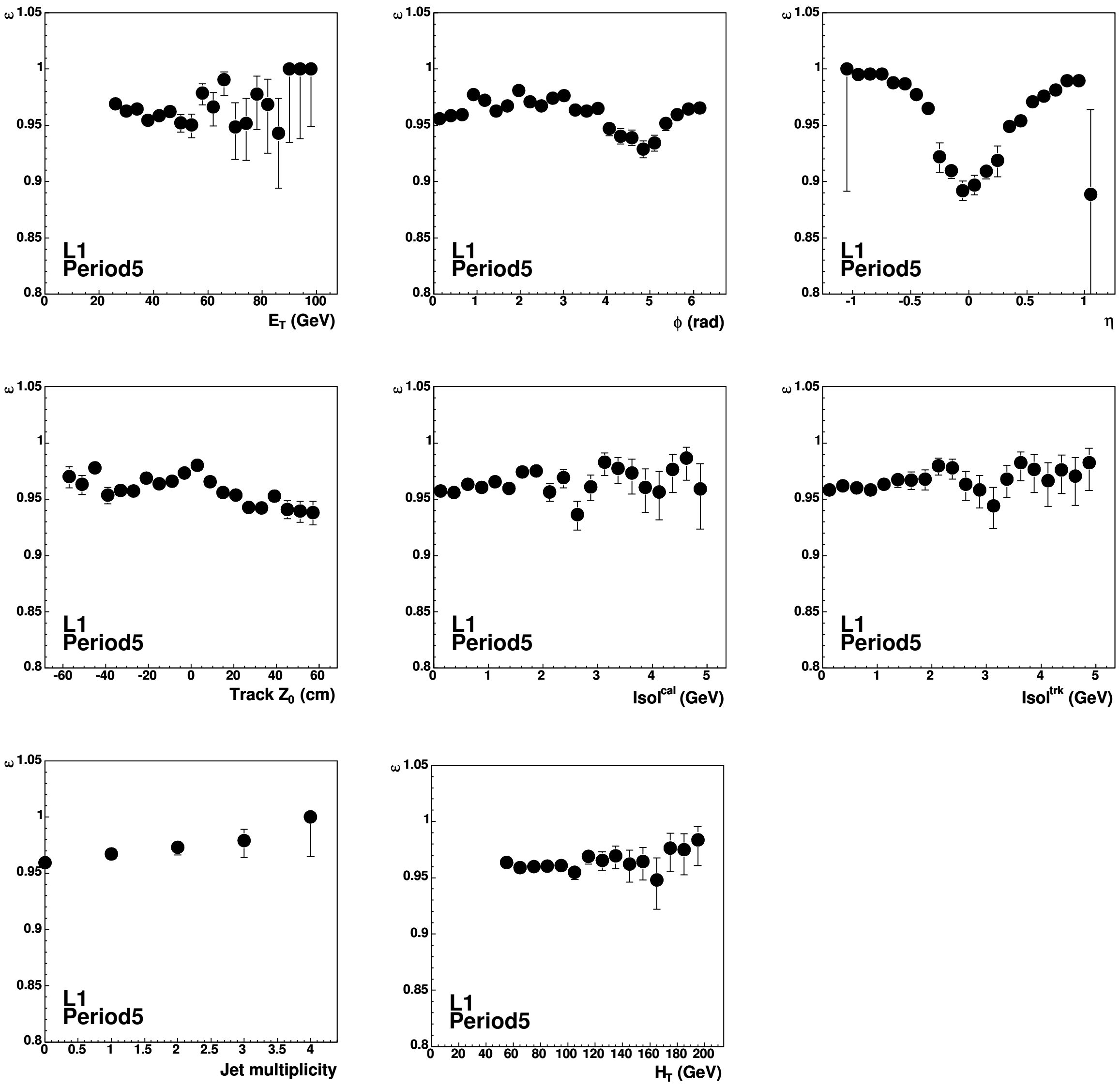


Figure 7: Level-1 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 5 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

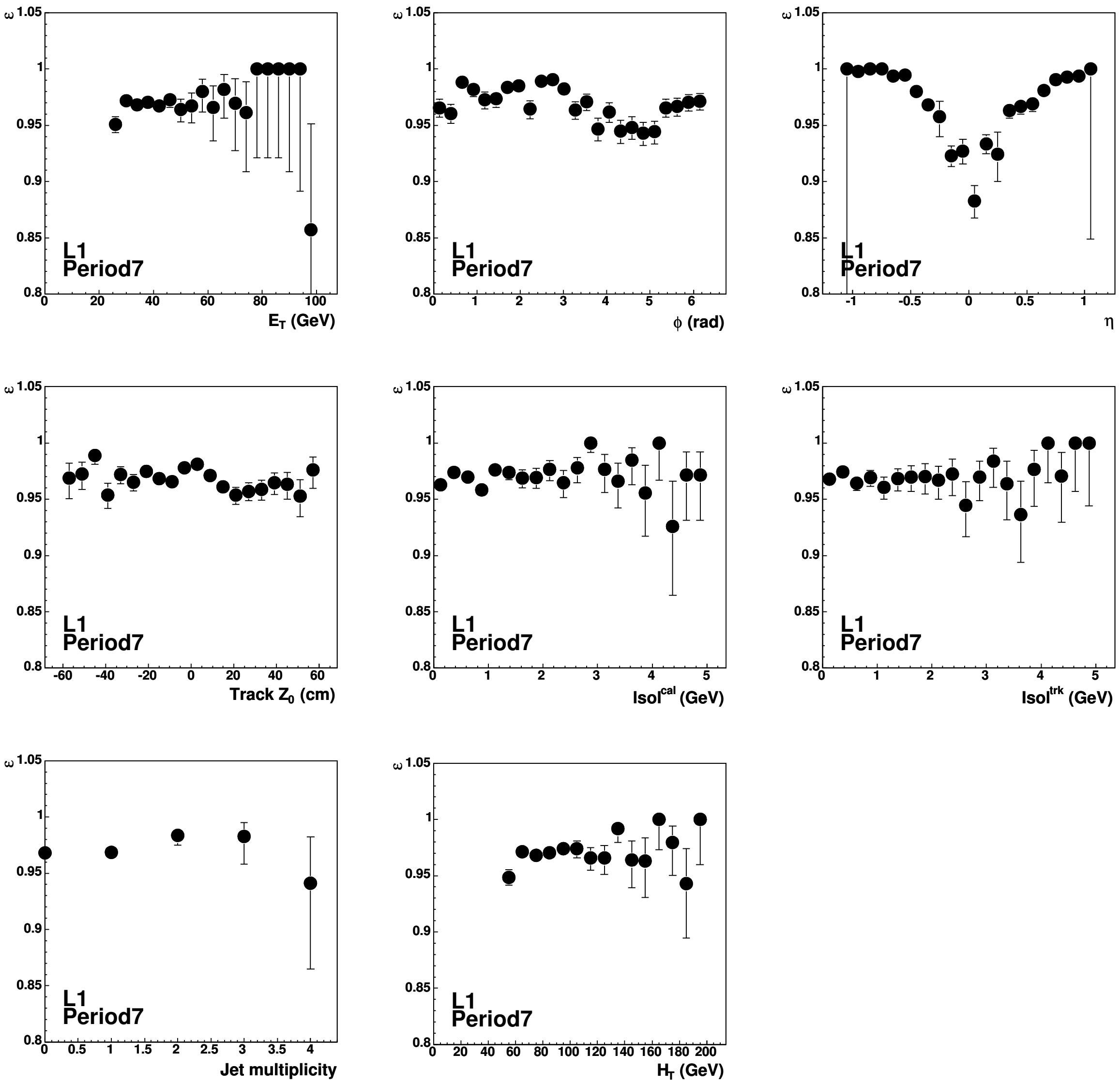


Figure 8: Level-1 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 7 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

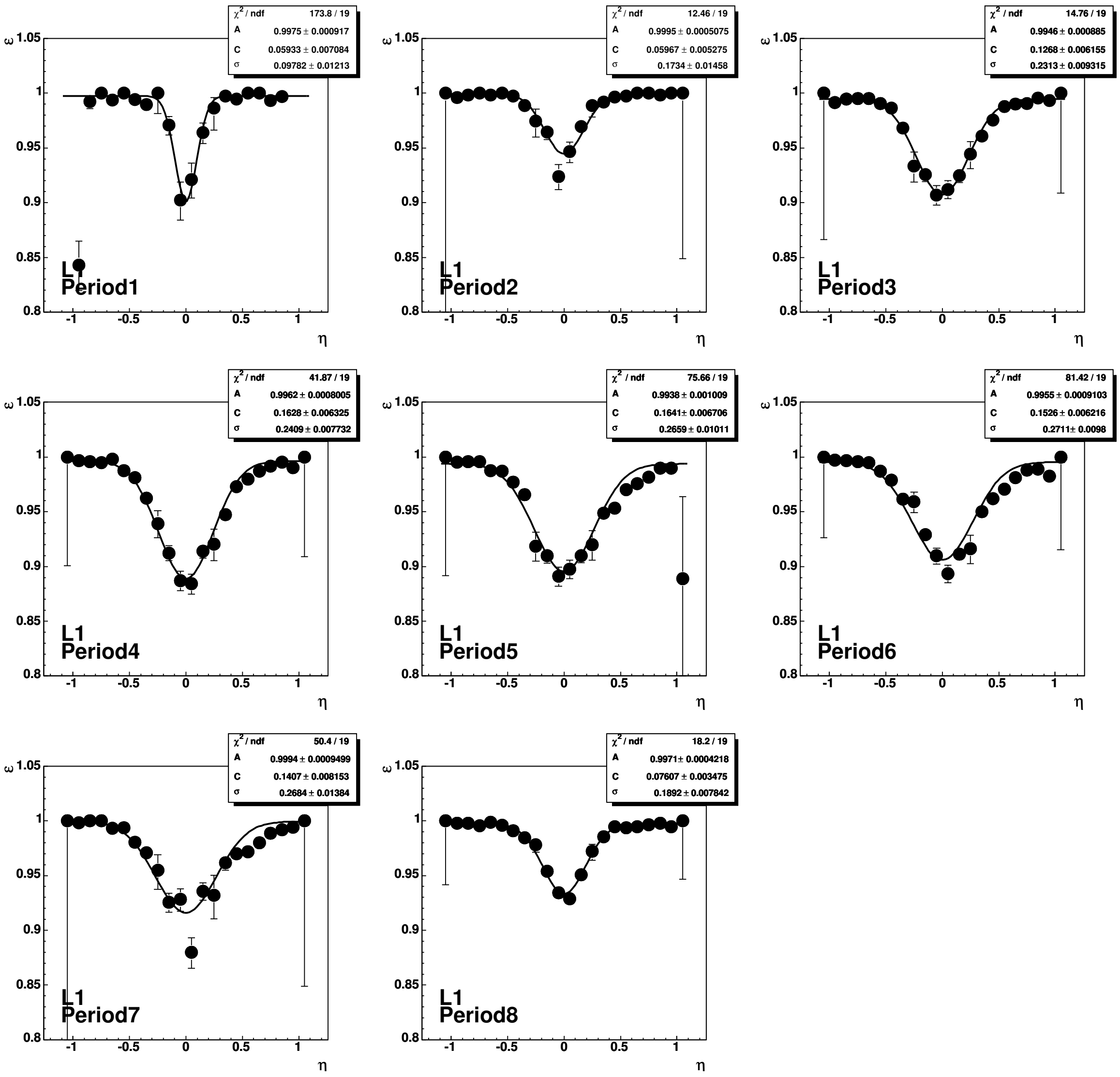


Figure 9: Level-1 tracking efficiency without silicon for electrons from $W^{\pm}$ decays in Periods 1 through 8 as a function of detector η measured by CES. Each plot is fitted to equation 2 and the fit parameters are given in Table 12.

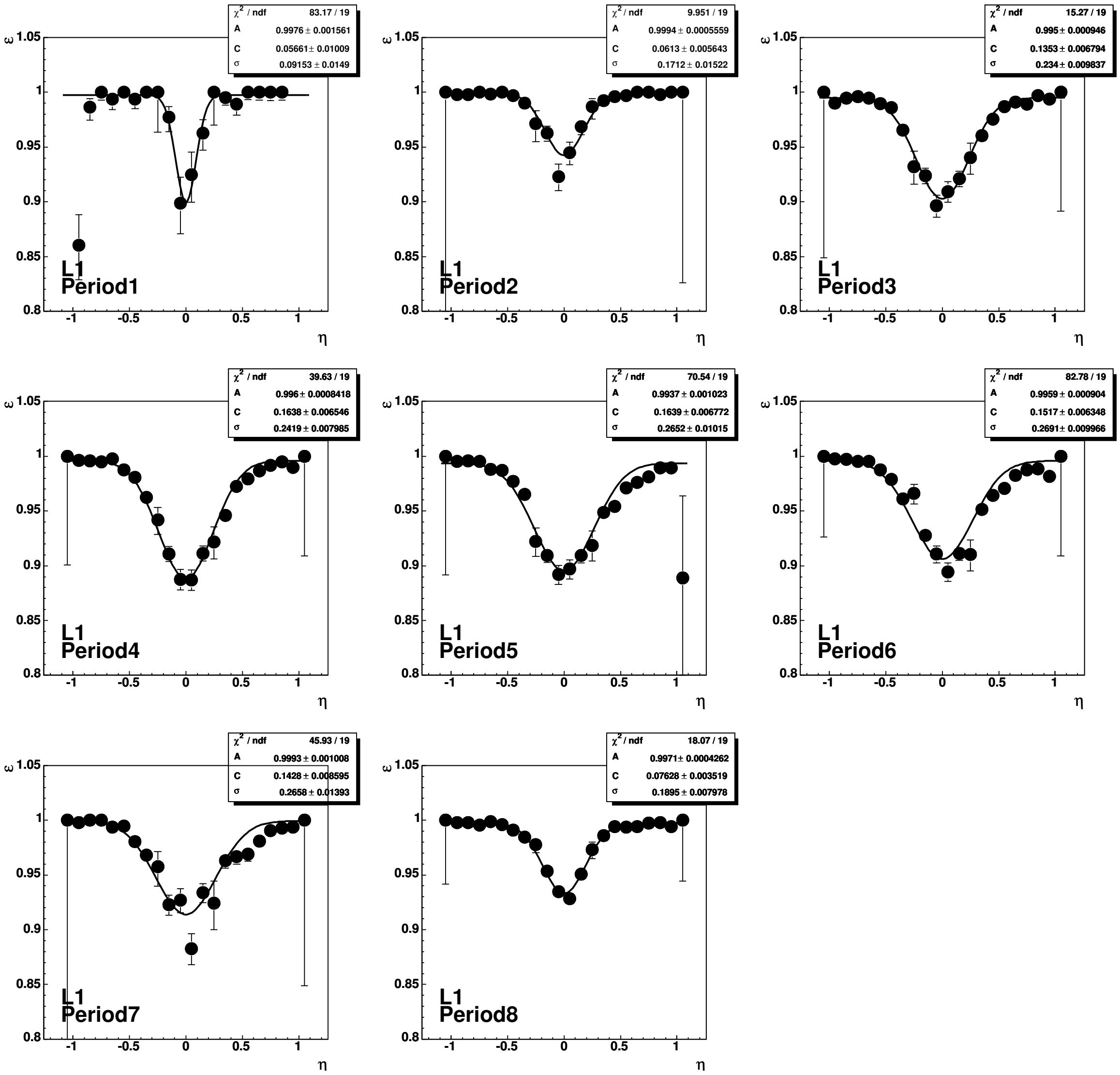


Figure 10: Level-1 tracking efficiency with silicon for electrons from $W^{\pm}$ decays in Periods 1 through 8 as a function of detector η measured by CES. Each plot is fitted to equation 2 and the fit parameters are given in Table 12.

Table 12: Fit values for L1 efficiency versus detector η for periods 1 through 8.

w/o silicon	A	C	σ
Period 1	0.9975(9)	0.0593(71)	0.0978(121)
Period 2	0.9995(5)	0.0597(53)	0.1734(146)
Period 3	0.9946(9)	0.1268(62)	0.2313(93)
Period 4	0.9962(8)	0.1628(63)	0.2409(77)
Period 5	0.9938(10)	0.1641(67)	0.2659(101)
Period 6	0.9955(9)	0.1526(62)	0.2711(98)
Period 7	0.9994(9)	0.1407(81)	0.2684(14)
Period 8	0.9971(4)	0.0761(35)	0.1892(78)

w/ silicon	A	C	σ
Period 1	0.9976(16)	0.0566(101)	0.0915(149)
Period 2	0.9994(6)	0.0613(56)	0.1712(152)
Period 3	0.9950(9)	0.1353(68)	0.2340(98)
Period 4	0.9960(8)	0.1638(65)	0.2419(80)
Period 5	0.9937(10)	0.1639(68)	0.2652(102)
Period 6	0.9959(9)	0.1517(63)	0.2691(100)
Period 7	0.9993(10)	0.1428(86)	0.2658(14)
Period 8	0.9971(4)	0.0763(35)	0.1895(80)

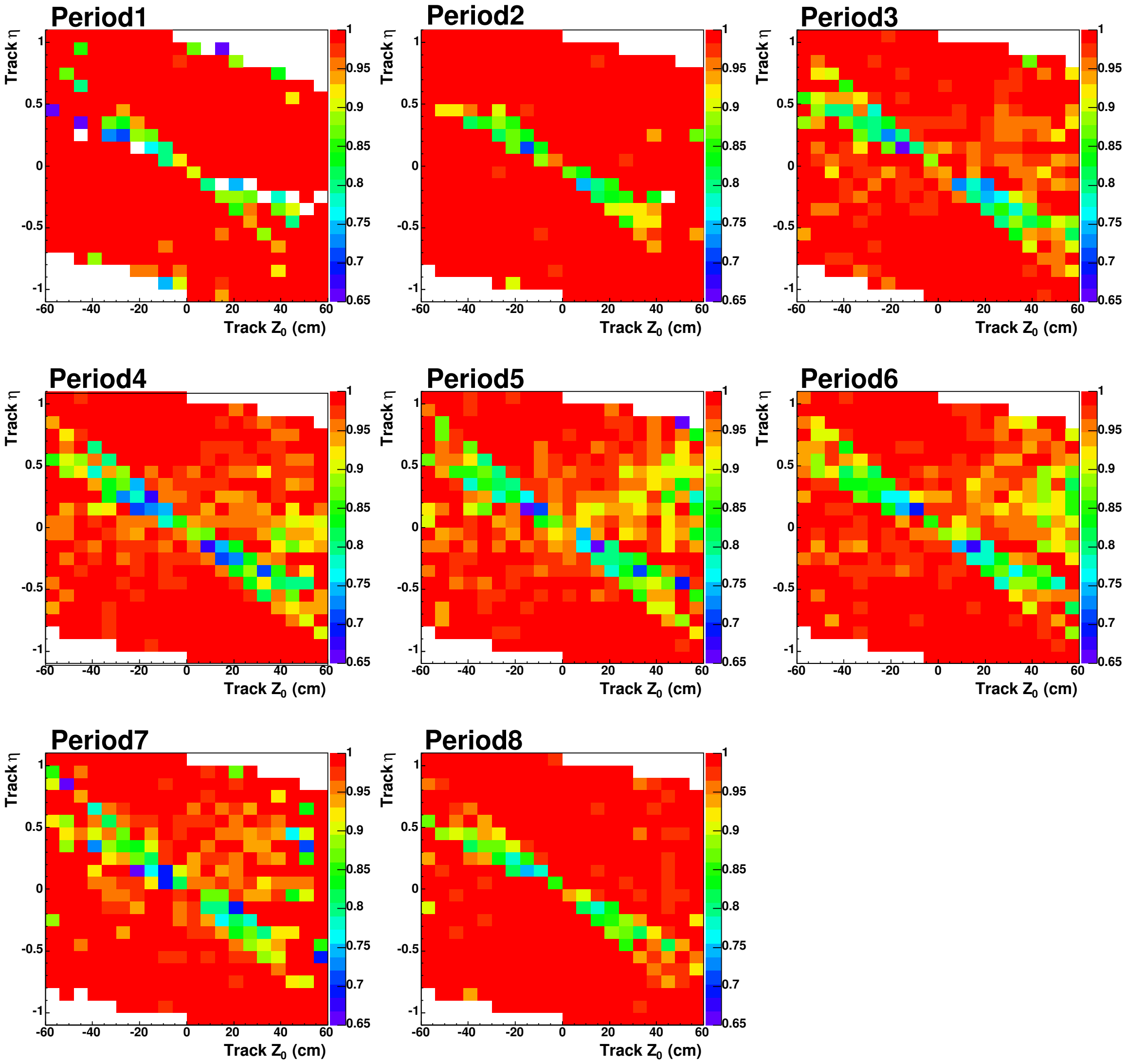


Figure 11: Level-1 tracking efficiency as a function of detector η and track Z_0 for 7 periods. The inefficiency is due to wire center support in COT.

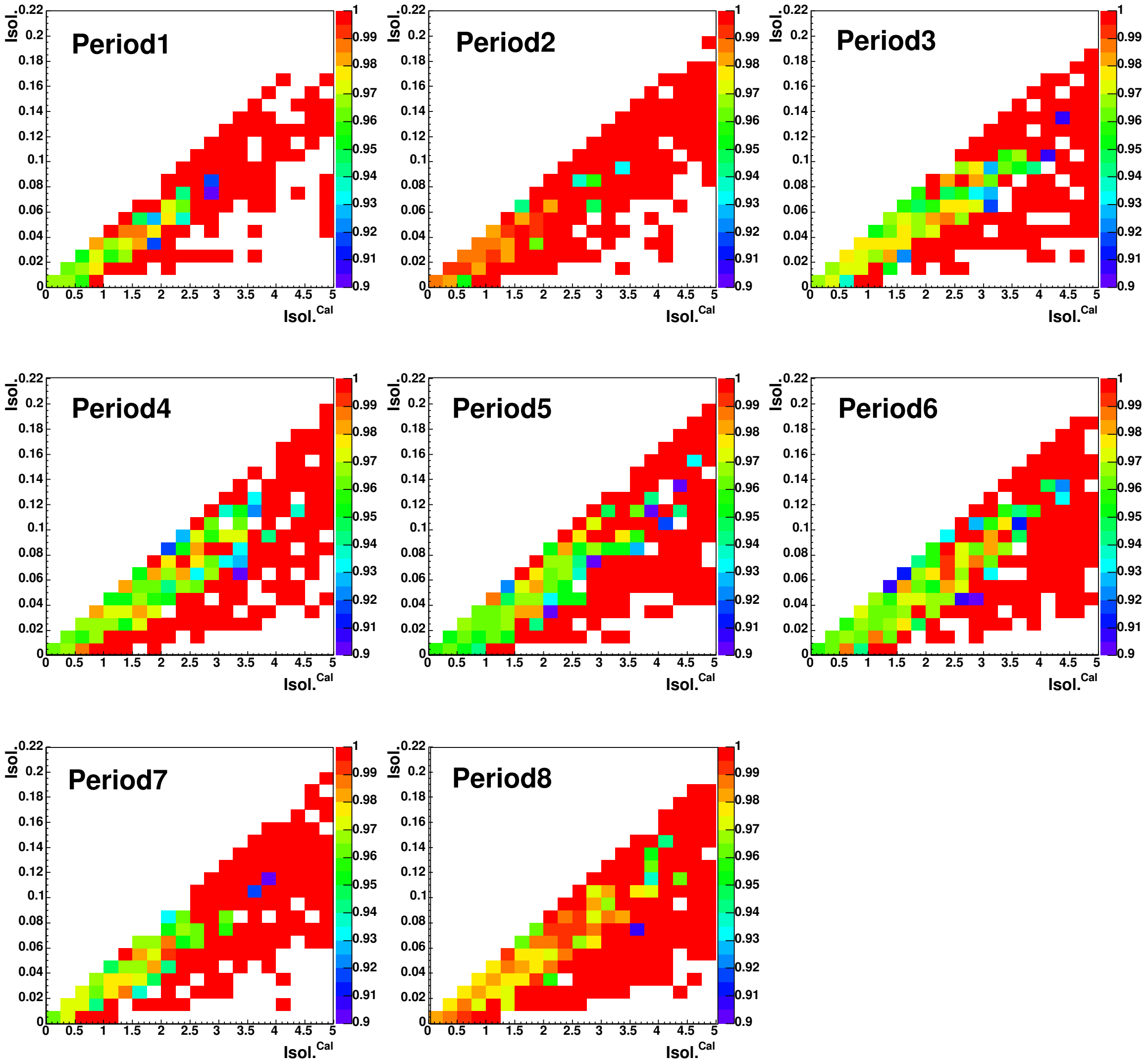


Figure 12: Level-1 tracking efficiency as a function of Isolation ratio and Isol.^{cal} for 7 periods.

Table 13: Level-2 tracking efficiencies and the number of events which failed Level-2 track trigger but pass Level-1 track trigger.

w/o silicon	Pass Level-1	Pass Level-2	Fail Level-2	Efficiency
Period 1	5903	5894	9	0.9985(6)
Period 2	12510	12499	11	0.9991(3)
Period 3	24591	24565	26	0.9989(2)
Period 4	26878	26849	29	0.9989(2)
Period 5	29472	29440	32	0.9989(2)
Period 6	31289	31241	48	0.9985(2)
Period 7	13306	13290	16	0.9988(3)
Period 8	40440	40403	37	0.9991(1)

w/ silicon	Pass Level-1	Pass Level-2	Fail Level-2	Efficiency
Period 1	2919	2913	6	0.9979(10)
Period 2	11228	11218	10	0.9991(3)
Period 3	20859	20837	22	0.9989(2)
Period 4	25599	25573	26	0.9990(2)
Period 5	28948	28917	31	0.9989(2)
Period 6	28773	28730	43	0.9985(2)
Period 7	12130	12115	15	0.9988(4)
Period 8	39387	39352	35	0.9991(1)

the high calorimeter isolation region corresponds to the high isolation region. the dependence of calorimeter isolation comes from electron fakes. The dependencies of track isolations and jet multiplicity also are caused by electron fakes.

3.3 Level-2 Tracking Efficiency

Level-1 passes the `XFT` information to Level-2. We check whether there are any errors in getting the `XFT` information into Level-2, namely, whether the Level-2 `PT8` bit is set when the Level-1 `PT8` bit is set:

$$\epsilon(\mathtt{L2\_XFT\_PT8}) = \frac{\#\text{ of } W'\text{s passing }\mathtt{L1\_CEM8\_PT8}\ \&\ \mathtt{L2\_XFT\_PT8}}{\#\text{ of } W'\text{s passing }\mathtt{L1\_CEM8\_PT8}}. \tag{3}$$

Table 13 shows the Level-2 tracking efficiencies and the number of events which failed Level-2 track trigger but pass Level-1 track trigger. We find 208 events and 188 events that failed passing the Level-1 information to Level-2, resulting in an efficiency of $(99.89 \pm 0.01)\%$ for both non-silicon and silicon good run lists.

3.4 Level-3 Tracking Efficiency

The Level-3 tracking efficiency is measured by requiring the L1_CEM8_PT8 and L2_CEM16_PT8 bits set and counting the $W^\pm$ events with the Level-3 Electron 18 bit set:

$$\epsilon(\texttt{L3\_PT9}) = \frac{\#\text{ of } W'\text{s passing }\texttt{L1\_CEM8\_PT8}\ \&\ \texttt{L2\_CEM16\_PT8}\ \&\ \texttt{L3\_CEM18\_PT9}}{\#\text{ of } W'\text{s passing }\texttt{L1\_CEM8\_PT8}\ \&\ \texttt{L2\_CEM16\_PT8}}. \quad (4)$$

The η-dependent trigger efficiency in periods 1 through 3 is fitted to

$$\epsilon(\text{L3\_PT9}) = \begin{cases} (-0.022 \pm 0.014) + (2.583 \pm 0.022) \cdot \eta + (-1.630 \pm 0.018) \cdot \eta^2 & (|\eta| > 0.8), \\ (0.9980 \pm 0.0002) & (|\eta| < 0.8), \end{cases} \quad (5)$$

for non-silicon good run list as shown in Figure 13 and

$$\epsilon(\text{L3\_PT9}) = \begin{cases} (-0.157 \pm 0.016) + (2.894 \pm 0.024) \cdot \eta + (-1.808 \pm 0.020) \cdot \eta^2 & (|\eta| > 0.8), \\ (0.9980 \pm 0.0003) & (|\eta| < 0.8), \end{cases} \quad (6)$$

for silicon good run list as shown in Figure 14, and the average trigger efficiency is measured to be $(99.29 \pm 0.04)\%$ and $(99.28 \pm 0.05)\%$ for non-silicon and silicon good run lists. The inefficiency at high $|\eta|$ occurs because the Level 3 tracking used during these periods requires all track seeds come from superlayer 8.

In Periods 4 through 8 we find an average Level-3 track trigger efficiency of $(99.79 \pm 0.01)\%$ for both good run lists. This increase in efficiency is expected due to the changes in the Level-3 tracking algorithm for high η (tracks with a seed superlayer other than 8) described in section 2. As expected, no η dependence is observed; see Figure 14.

The efficiency dependence on kinematic variables of tracks and event conditions is shown in Figure 15, 16, 17, 18, 19, 20, 21 and 22. We did not observe any dependence except η dependence with $|\eta| > 0.8$ in Period 3 as discussed in the previous paragraphs. Tables 14, 15, 16, 17 and 18 summarize the Level-3 tracking efficiencies for all run periods.

3.5 Summary

Table 19 summarizes the average efficiencies of track triggers for the high E_T electron trigger at Level-1, Level-2, and Level-3 for eight data-taking periods. The total average track trigger efficiencies are $(96.59 \pm 0.04)\%$ for Periods 1-7 which corresponds to the DQM 7.0 non-silicon and silicon good run lists. Figure 23 and 24 show the trigger efficiencies as a function of the run number or time.

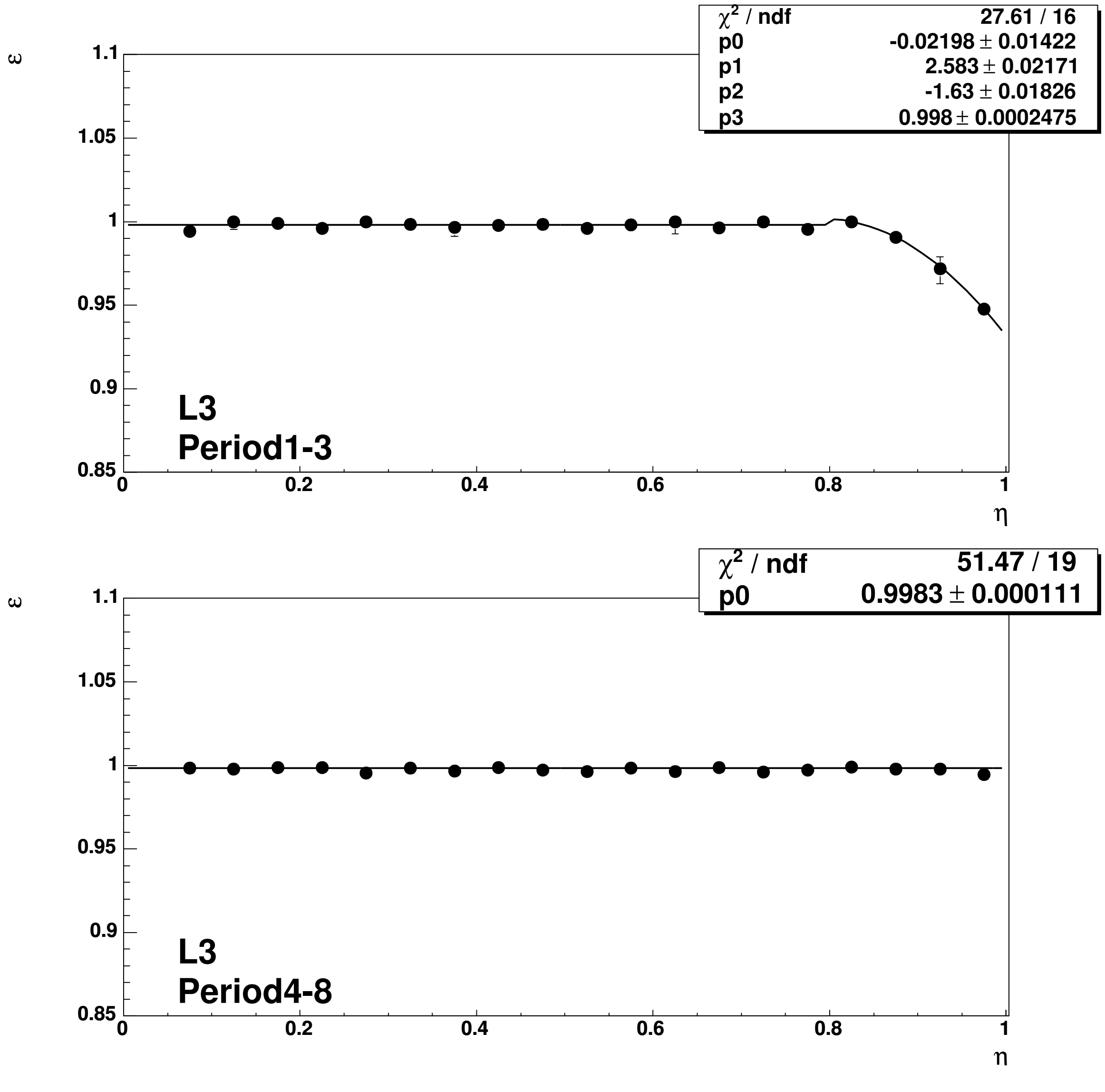
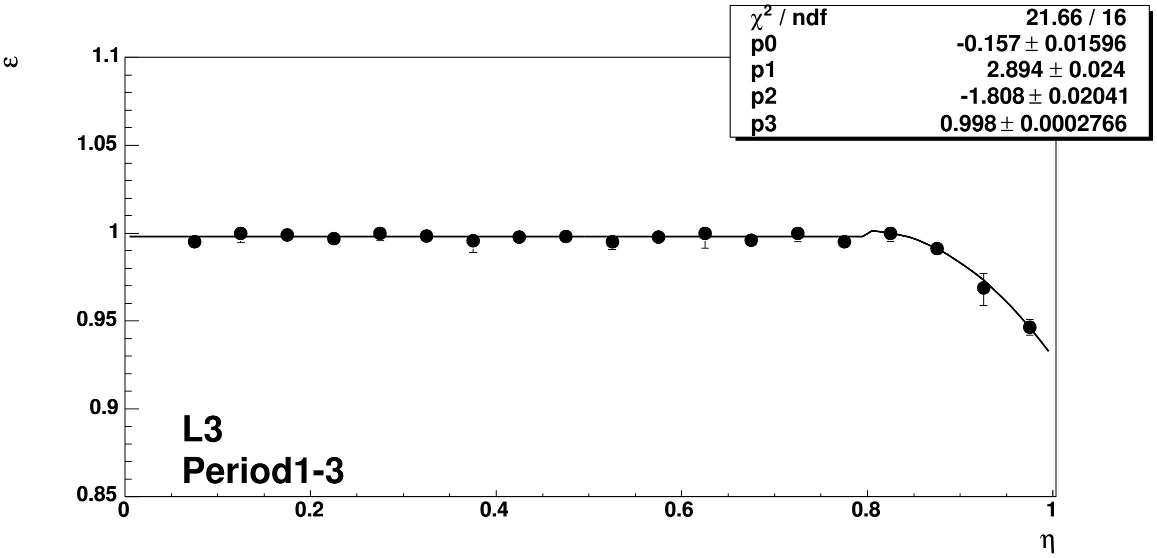


Figure 13: Level-3 tracking efficiencies without silicon good run list as a function of detector η measured by CES for Period 1, 2, and 3 combined (top) and Period 4, 5, 6 and 7 combined (bottom).



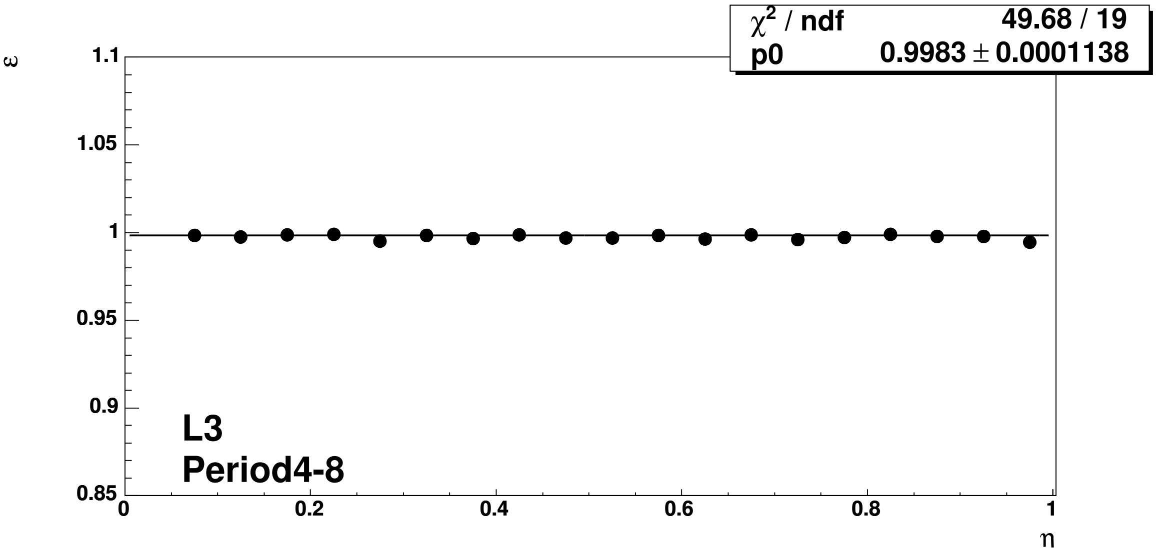


Figure 14: Level-3 tracking efficiencies with silicon good run list as a function of detector η measured by `CES` for Period 1, 2, and 3 combined (top) and Period 4, 5, 6 and 7 combined (bottom).

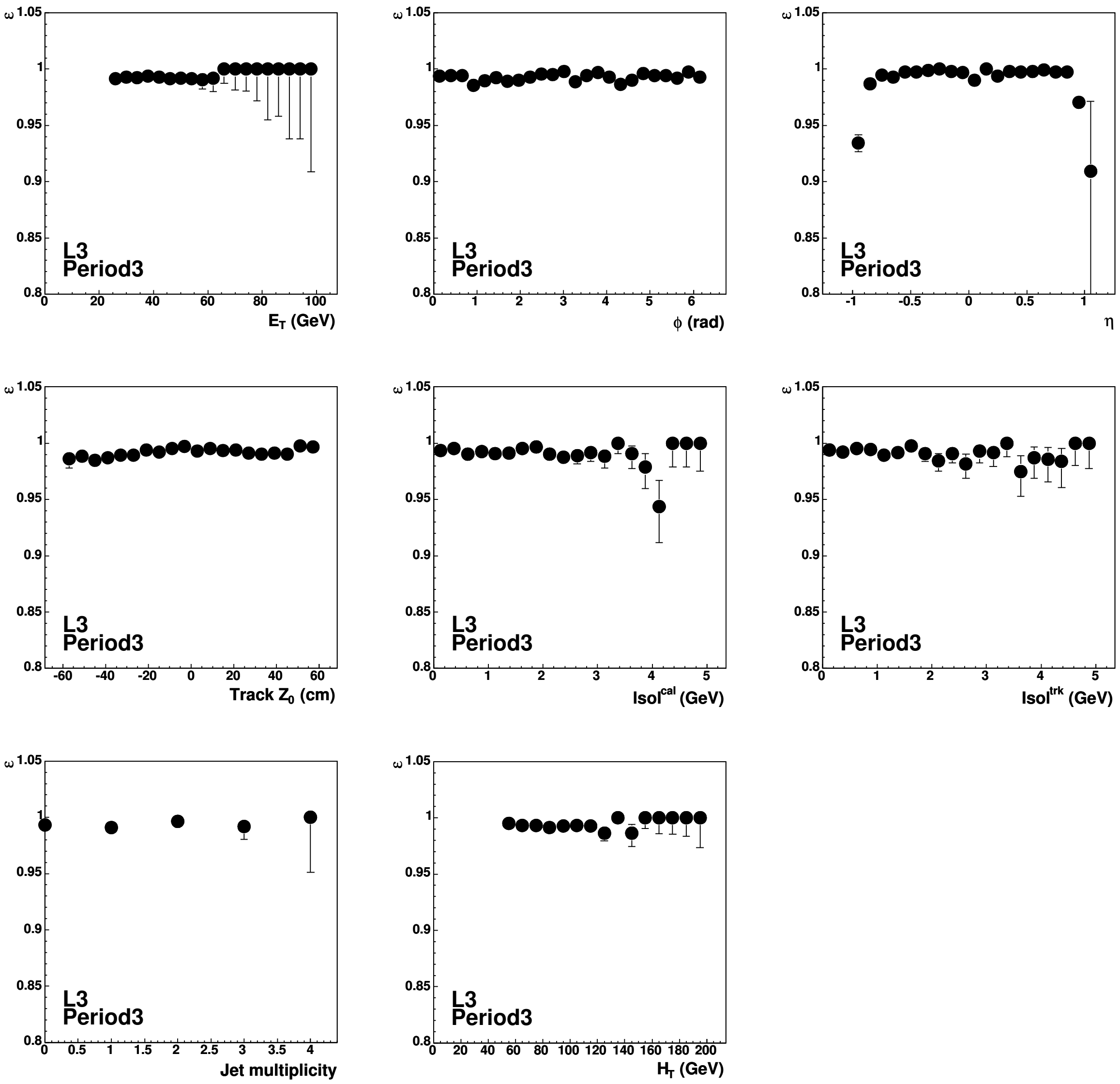


Figure 15: Level-3 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 3 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

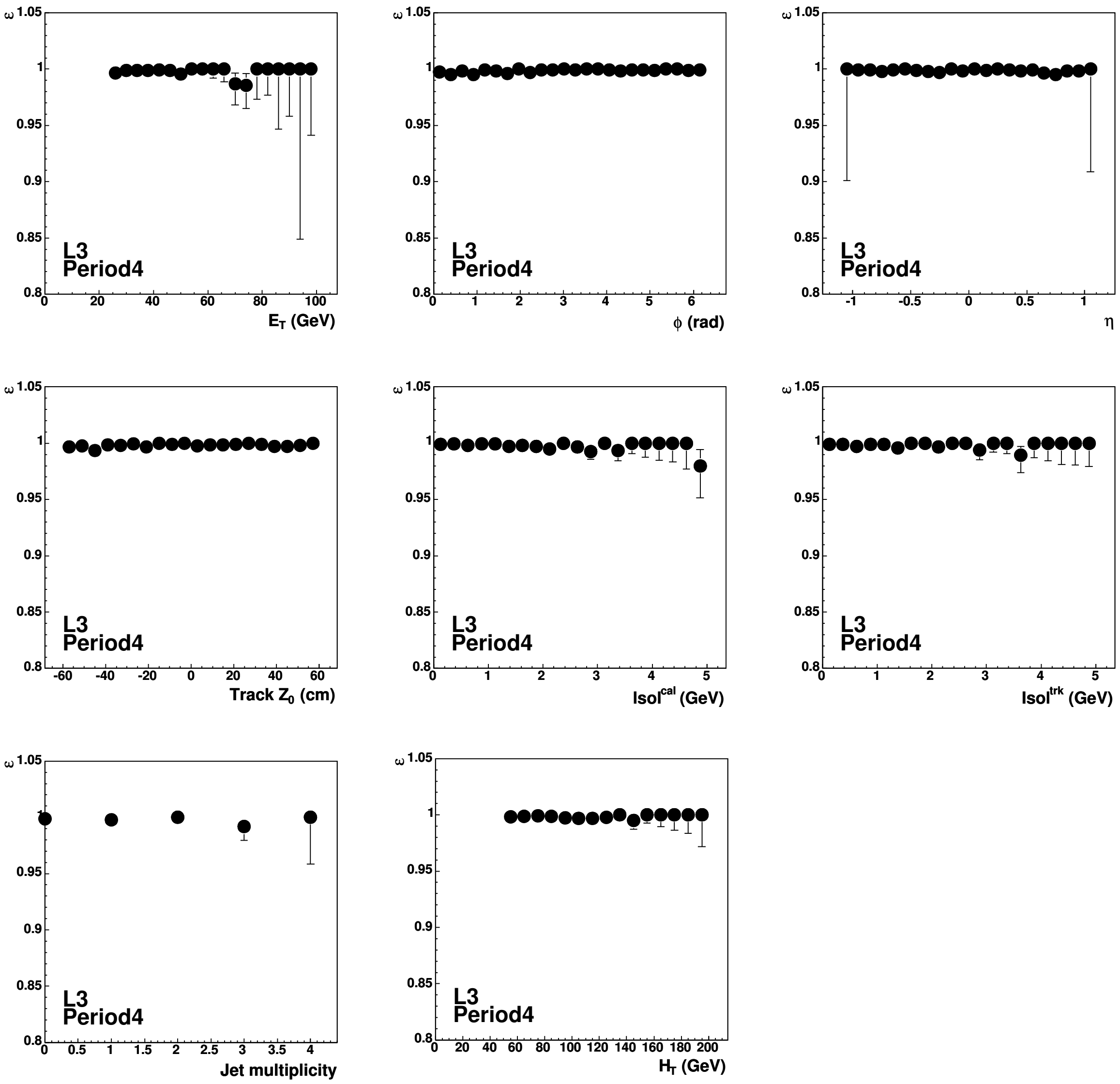


Figure 16: Level-3 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 4 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

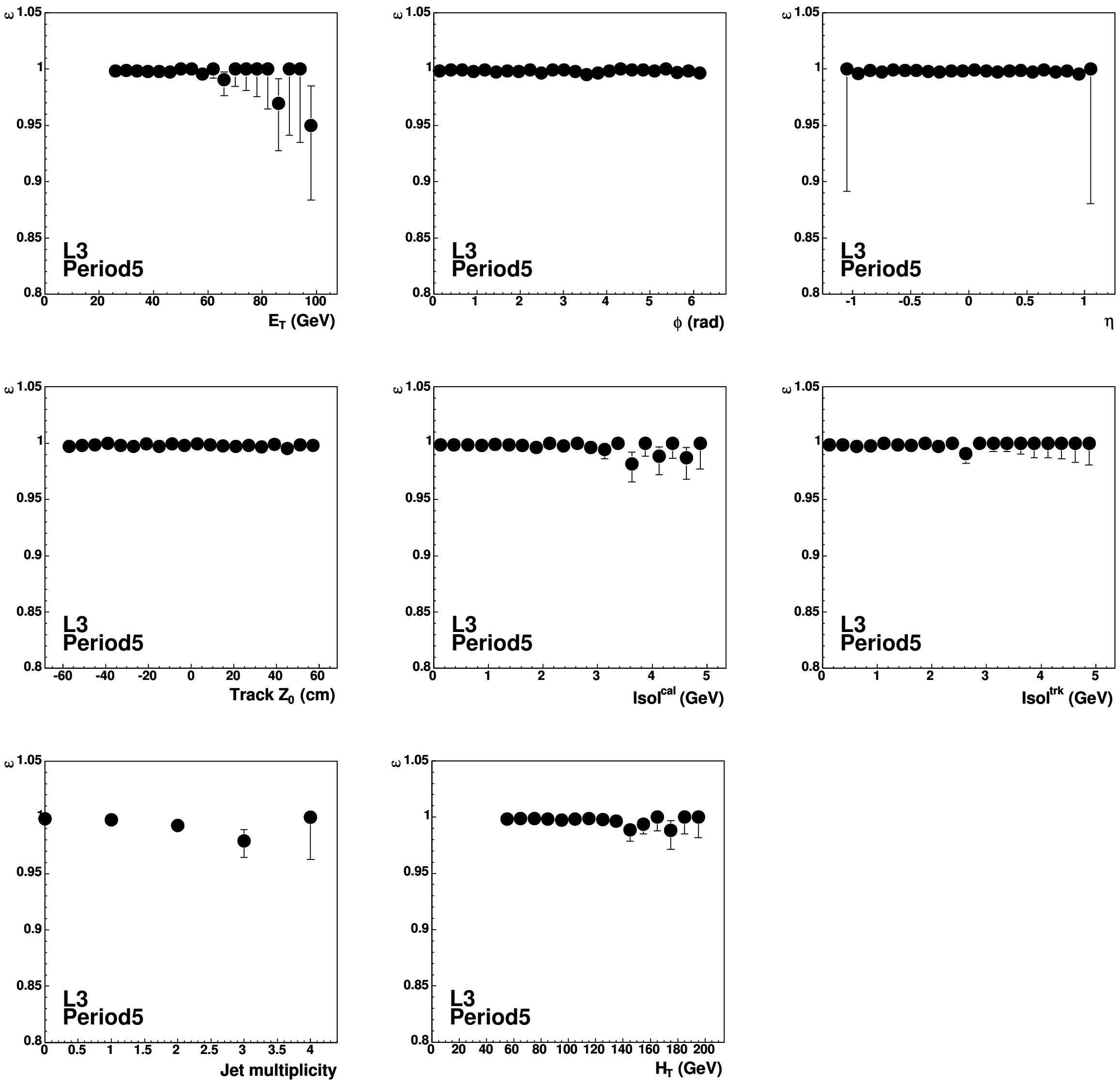


Figure 17: Level-3 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 5 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

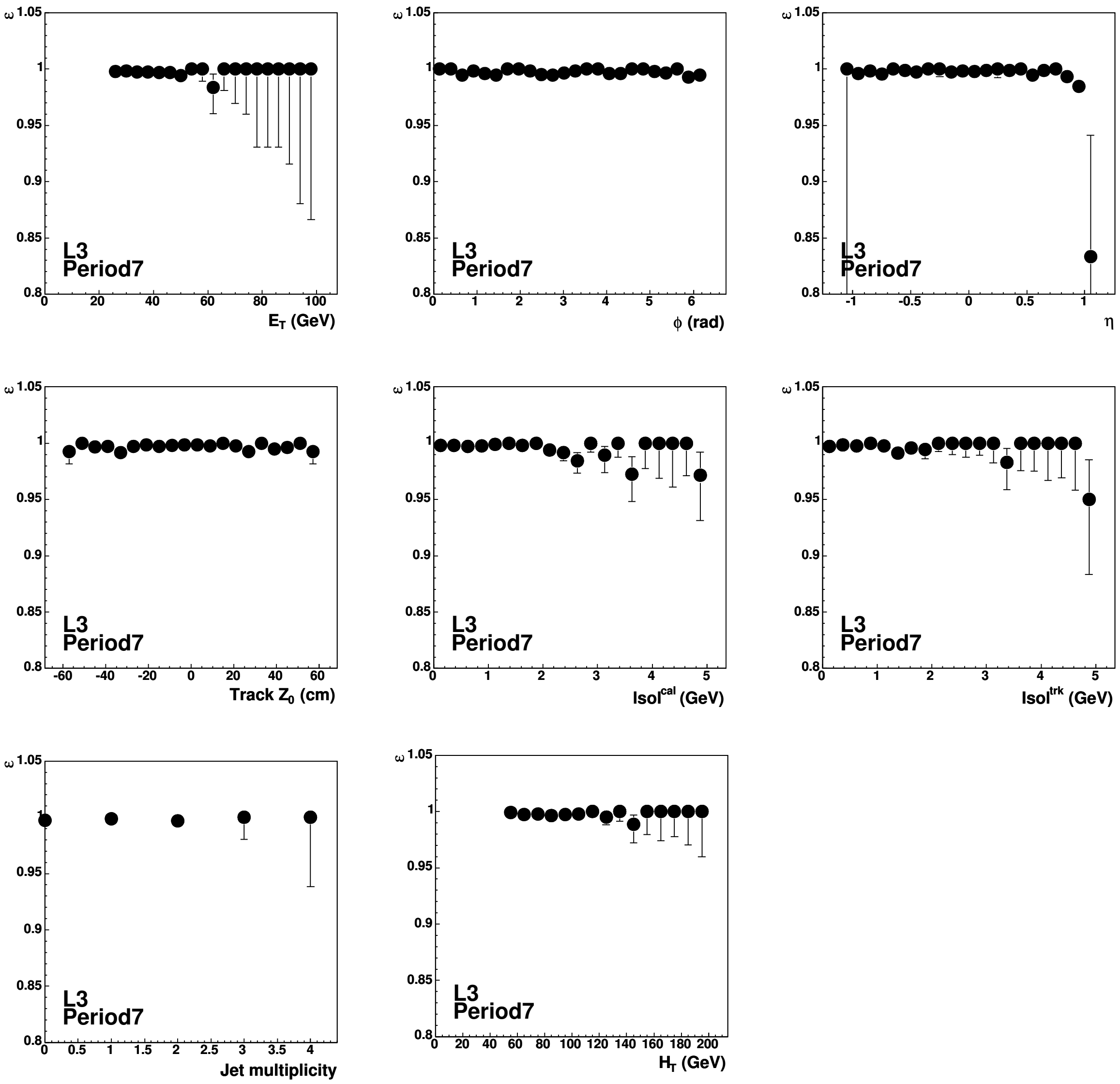


Figure 18: Level-3 tracking efficiency without silicon good run list for electrons from $W^{\pm}$ decays in Period 7 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

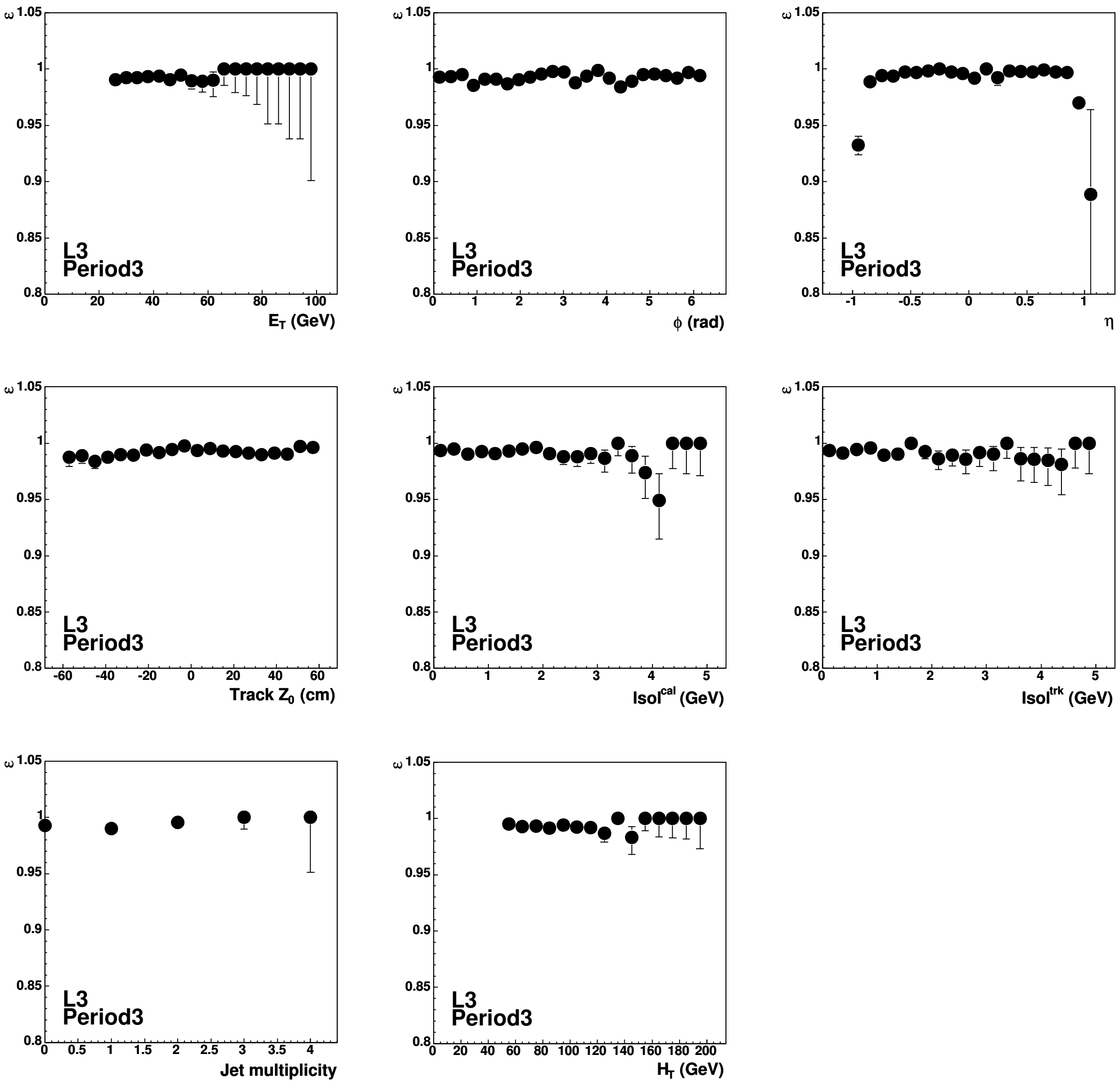


Figure 19: Level-3 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 3 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

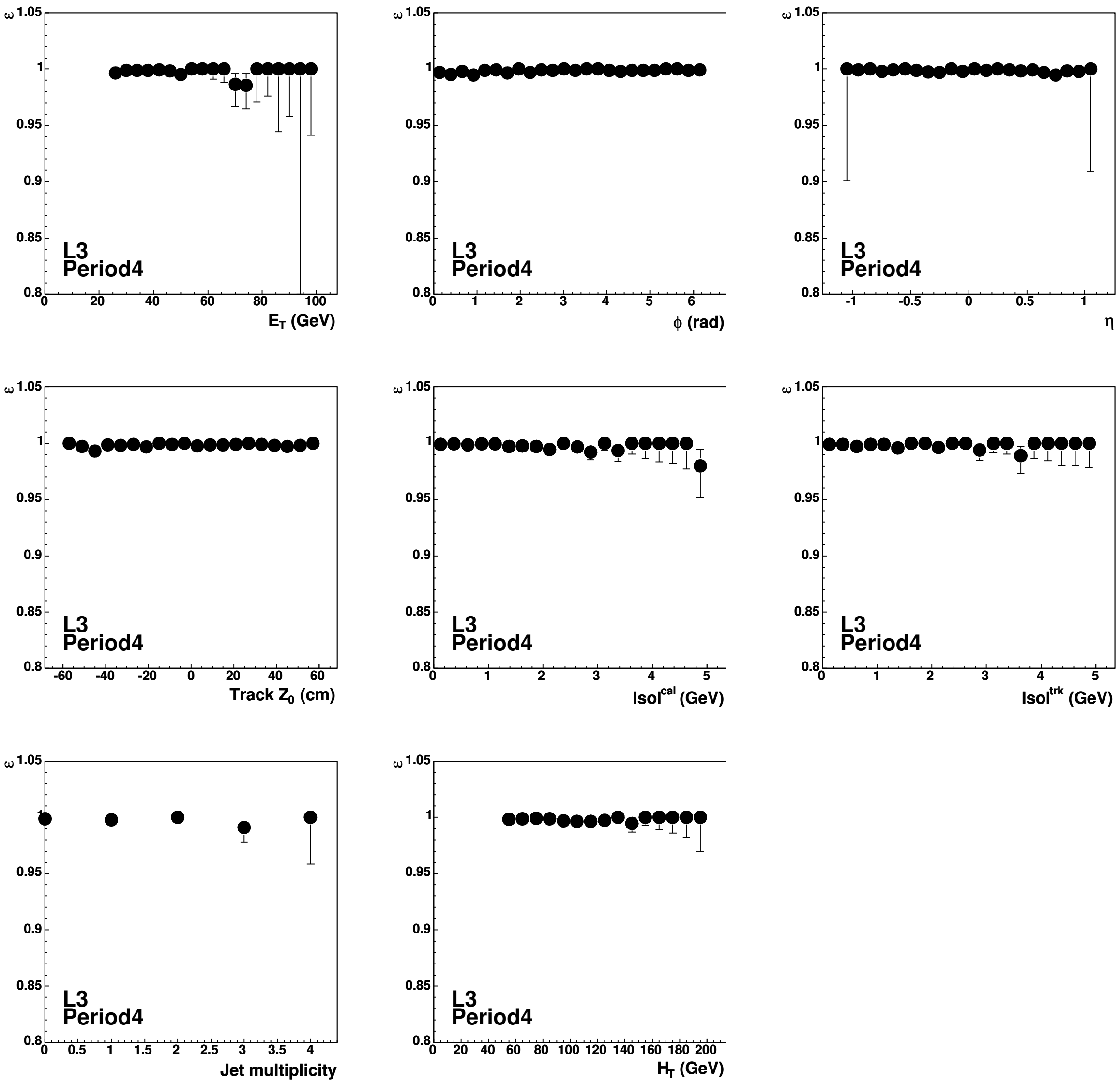


Figure 20: Level-3 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 4 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

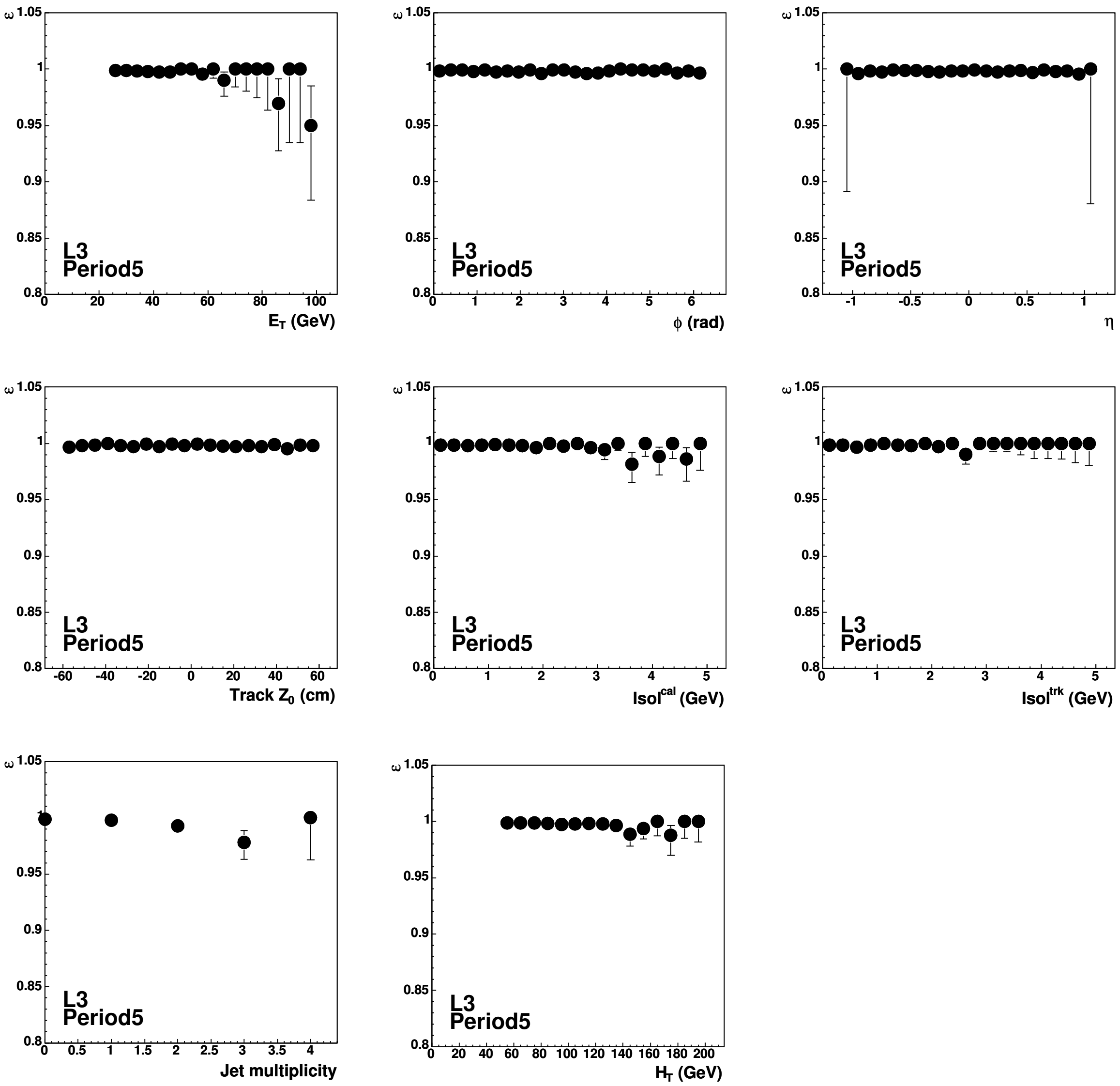


Figure 21: Level-3 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 5 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

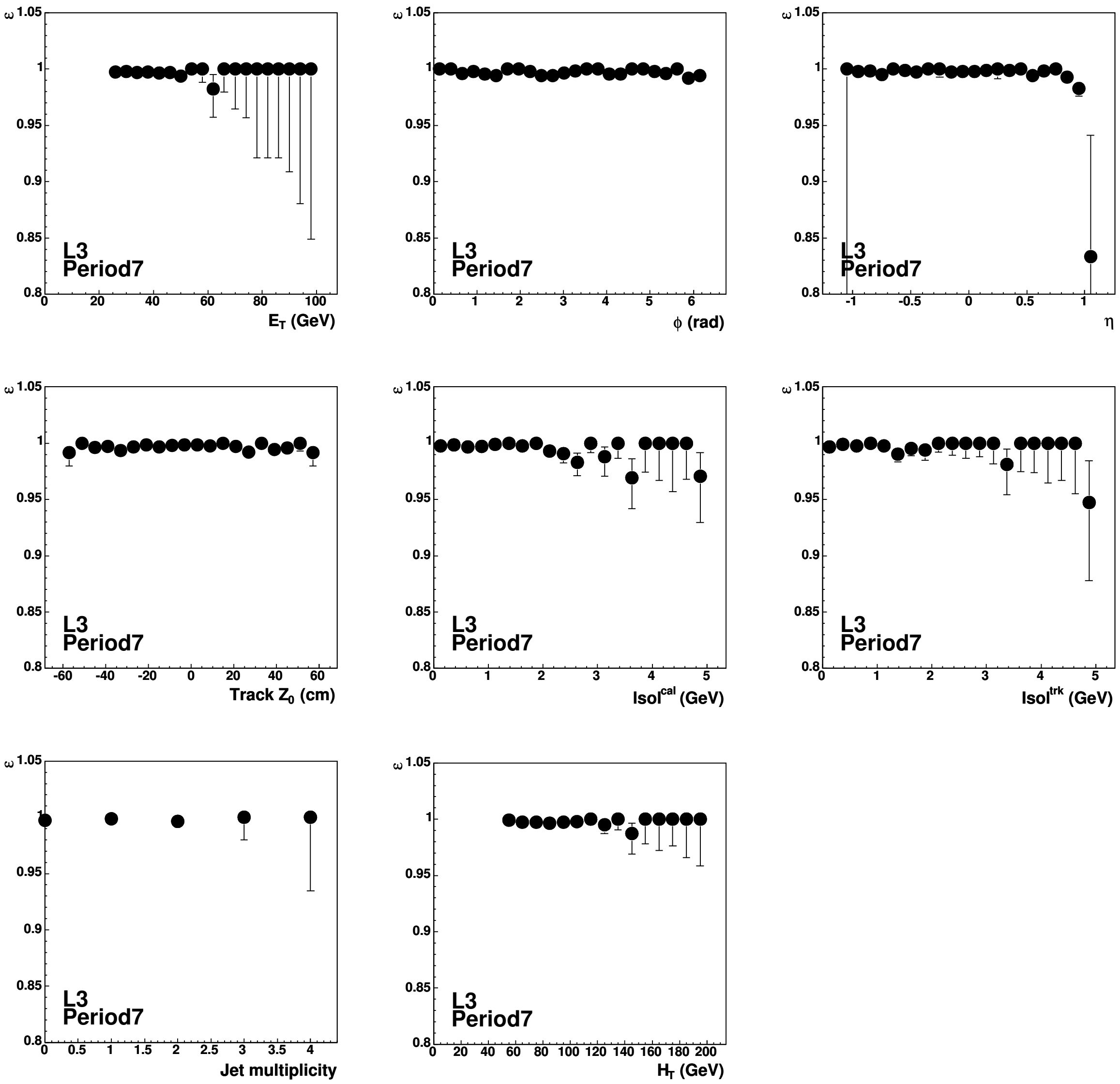


Figure 22: Level-3 tracking efficiency with silicon good run list for electrons from $W^{\pm}$ decays in Period 7 as a function of p_T, ϕ, detector η, track Z_0, calorimeter isolation, track isolation, jet multiplicity and H_T.

Table 14: Level-3 tracking efficiencies with $W^{\pm}$ candidates. Electrons are required to pass the "baseline cuts" described in Table 5.

	w/o silicon	w/ silicon
Period 1	0.9961(9)	0.9969(12)
Period 2	0.9916(8)	0.9918(9)
Period 3	0.9928(5)	0.9927(6)
Period 4	0.9986(2)	0.9986(2)
Period 5	0.9982(3)	0.9982(3)
Period 6	0.9983(2)	0.9984(3)
Period 7	0.9975(5)	0.9974(5)
Period 8	0.9972(2)	0.9972(3)

Table 15: Level-3 tracking efficiency for jet multiplicity selection cut with $W^{\pm}$ candidates.

w/o silicon	no jets in $\|\eta_{jet}\| < 1.2$	≥ 1 jets in $\|\eta_{jet}\| < 1.2$
Period 1	0.9959(10)	0.9975(23)
Period 2	0.9914(9)	0.9927(22)
Period 3	0.9930(6)	0.9916(16)
Period 4	0.9987(3)	0.9980(8)
Period 5	0.9985(3)	0.9963(10)
Period 6	0.9985(3)	0.9973(8)
Period 7	0.9973(5)	0.9985(11)
Period 8	0.9974(3)	0.9960(9)

w/ silicon	no jets in $\|\eta_{jet}\| < 1.2$	≥ 1 jets in $\|\eta_{jet}\| < 1.2$
Period 1	0.9964(13)	1.0000(30)
Period 2	0.9915(10)	0.9937(22)
Period 3	0.9930(6)	0.9911(18)
Period 4	0.9987(3)	0.9979(9)
Period 5	0.9985(3)	0.9963(10)
Period 6	0.9986(3)	0.9972(9)
Period 7	0.9972(6)	0.9984(12)
Period 8	0.9974(3)	0.9960(9)

Table 16: Level-3 tracking efficiency for calorimeter isolation selection cut with $W^{\pm}$ candidates.

w/o silicon	Cal. Isol. < 2 GeV	Cal. Isol. > 2 GeV
Period 1	0.9961(9)	0.9962(35)
Period 2	0.9921(9)	0.9869(37)
Period 3	0.9933(6)	0.9890(22)
Period 4	0.9989(2)	0.9962(13)
Period 5	0.9984(3)	0.9962(12)
Period 6	0.9984(3)	0.9976(10)
Period 7	0.9981(4)	0.9931(23)
Period 8	0.9977(3)	0.9936(12)

w/ silicon	Cal. Isol. < 2 GeV	Cal. Isol. > 2 GeV
Period 1	0.9970(12)	0.9959(61)
Period 2	0.9923(9)	0.9873(39)
Period 3	0.9932(6)	0.9885(24)
Period 4	0.9989(2)	0.9961(13)
Period 5	0.9985(3)	0.9961(12)
Period 6	0.9985(3)	0.9974(10)
Period 7	0.9980(5)	0.9925(25)
Period 8	0.9977(3)	0.9937(12)

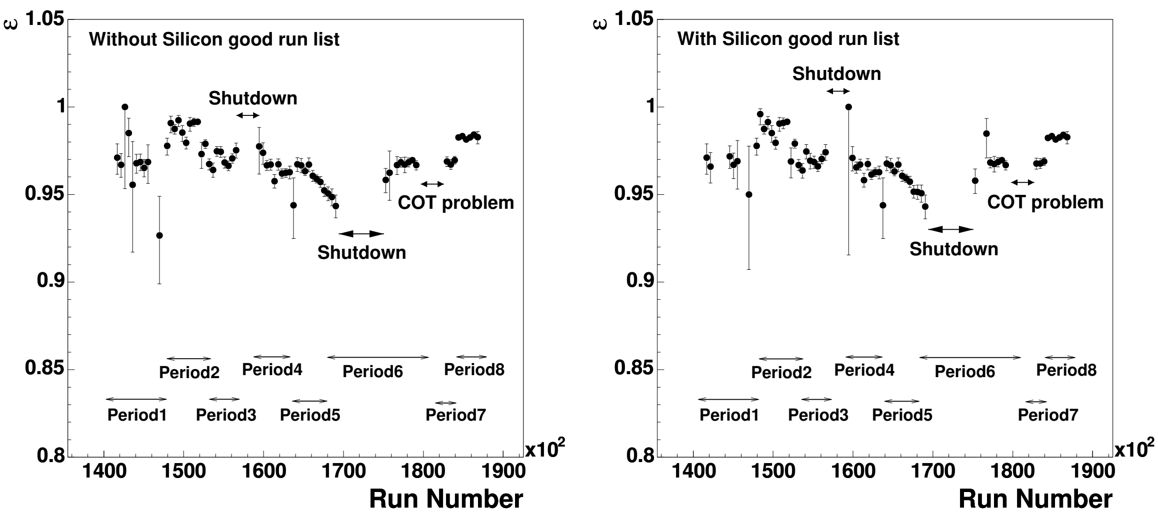


Figure 23: Level-1 tracking trigger efficiency as a function of the run number.

Table 17: Level-3 tracking efficiency for track isolation selection cut with $W^{\pm}$ candidates.

w/o silicon	Track Isol. < 1 GeV	Track Isol. > 1 GeV
Period 1	0.9965(9)	0.9945(26)
Period 2	0.9920(9)	0.9898(23)
Period 3	0.9937(6)	0.9893(16)
Period 4	0.9989(2)	0.9971(8)
Period 5	0.9985(3)	0.9970(8)
Period 6	0.9985(3)	0.9975(7)
Period 7	0.9977(5)	0.9969(13)
Period 8	0.9973(3)	0.9966(7)

w/ silicon	Track Isol. < 1 GeV	Track Isol. > 1 GeV
Period 1	0.9975(12)	0.9943(40)
Period 2	0.9923(10)	0.9897(24)
Period 3	0.9934(6)	0.9896(17)
Period 4	0.9989(2)	0.9972(8)
Period 5	0.9985(3)	0.9970(8)
Period 6	0.9986(3)	0.9973(8)
Period 7	0.9975(5)	0.9966(14)
Period 8	0.9972(3)	0.9966(7)

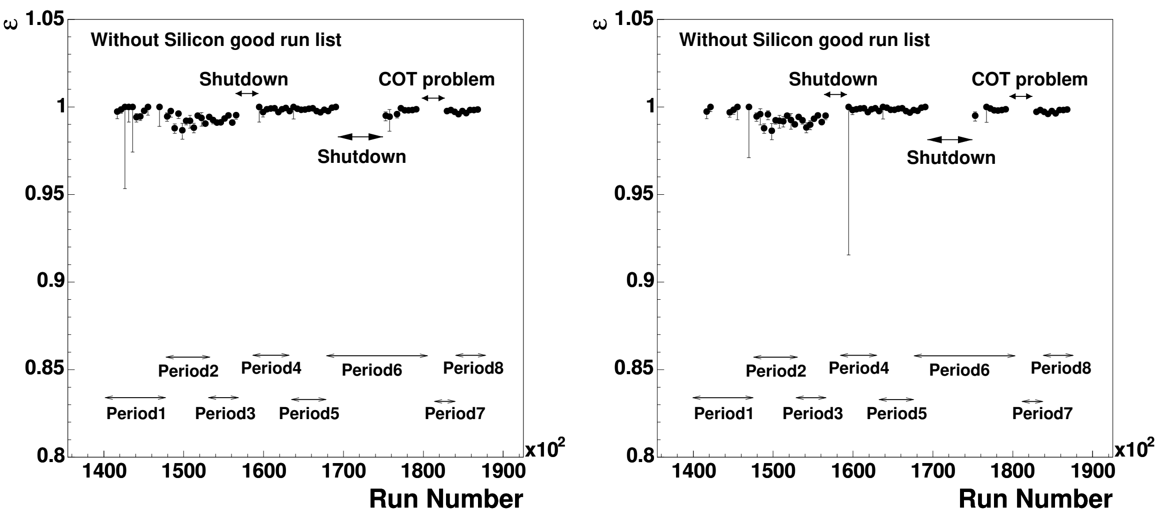


Figure 24: Level-3 tracking trigger efficiency as a function of the run number.

Table 18: Level-3 tracking efficiency for H_T selection cut with $W^{\pm}$ candidates.

w/o silicon	$H_T < 100$ GeV	$H_T > 100$ GeV
Period 1	0.9958(10)	0.9985(23)
Period 2	0.9917(9)	0.9910(27)
Period 3	0.9929(6)	0.9923(18)
Period 4	0.9988(2)	0.9972(11)
Period 5	0.9985(3)	0.9962(12)
Period 6	0.9983(3)	0.9979(8)
Period 7	0.9974(5)	0.9981(13)
Period 8	0.9972(3)	0.9967(9)

w/ silicon	$H_T < 100$ GeV	$H_T > 100$ GeV
Period 1	0.9965(13)	1.0000(37)
Period 2	0.9918(9)	0.9915(28)
Period 3	0.9928(6)	0.9918(20)
Period 4	0.9988(2)	0.9970(11)
Period 5	0.9985(3)	0.9961(12)
Period 6	0.9985(3)	0.9977(9)
Period 7	0.9973(5)	0.9980(14)
Period 8	0.9973(3)	0.9966(9)

Table 19: The track trigger efficiencies for the high E_T electrons (trigger path name ELECTRON_CENTRAL_18).

w/o silicon	L1 XFT PT8	L2 XFT PT8	L3 Tracking	Total
Period 1	0.9680(23)	0.9985(6)	0.9961(9)	0.9628(25)
Period 2	0.9875(10)	0.9991(3)	0.9916(8)	0.9783(13)
Period 3	0.9699(11)	0.9989(2)	0.9928(5)	0.9619(12)
Period 4	0.9639(11)	0.9989(2)	0.9986(2)	0.9615(12)
Period 5	0.9607(11)	0.9989(2)	0.9982(3)	0.9579(12)
Period 6	0.9638(10)	0.9985(2)	0.9983(2)	0.9606(11)
Period 7	0.9789(15)	0.9988(3)	0.9975(5)	0.9653(16)
Period 8	0.9822(7)	0.9991(1)	0.9972(2)	0.9785(7)

w/ silicon	L1 XFT PT8	L2 XFT PT8	L3 Tracking	Total
Period 1	0.9701(32)	0.9979(10)	0.9969(12)	0.9651(35)
Period 2	0.9872(11)	0.9991(3)	0.9918(9)	0.9782(14)
Period 3	0.9687(12)	0.9989(2)	0.9927(6)	0.9606(13)
Period 4	0.9636(11)	0.9990(2)	0.9986(2)	0.9612(12)
Period 5	0.9607(11)	0.9989(2)	0.9982(3)	0.9579(12)
Period 6	0.9641(11)	0.9985(2)	0.9984(3)	0.9611(11)
Period 7	0.9784(16)	0.9988(4)	0.9974(5)	0.9646(17)
Period 8	0.9821(7)	0.9991(1)	0.9972(3)	0.9785(7)

4 Calorimeter Trigger Efficiencies

In this section we measure the calorimeter trigger efficiency for Level-2. We do not measure the efficiencies for Level-1 and Level-3 in this study, since we expect the efficiencies are almost 100% from the previous study. We refer the reader to sections 4 of the dedicated note [6] for a detailed discussion of the calorimeter trigger efficiencies.

4.1 Level-2 Calorimeter Trigger Efficiency

The `L1_CEM8_PT8` trigger feeds both `L2_CEM16_PT8` and `L2_PS50_L1_CEM8_PT8` triggers. The `L2_CEM16_PT8` trigger requires a Level-2 central cluster with `EM` $E_T \geq 16$ GeV (the `PT8` requirement has been satisfied at Level-1) while the `L2_PS50_L1_CEM8_PT8` trigger auto-accepts a fraction of events. We measure the `L2_CEM16` trigger efficiency from this auto-accepted sample.

We apply the baseline cuts shown in Table 5 with a lower E_T cut of 18 GeV and require the isolation ratio be less than 0.1. The E_T distributions of electron candidates and the resulting `L2_CEM16` trigger efficiencies are shown in Figure 25 and 26 for the complete dataset. The efficiency, $\epsilon(\texttt{L2\_CEM16})$, is fitted to a function

$$\epsilon(\texttt{L2\_CEM16}) = p2 - p0 \cdot \exp(-p1 \cdot E_T). \tag{7}$$

The `L2_CEM16` trigger fires for about 96% of electrons at $E_T \simeq 20$ GeV and the efficiency reaches up to 100% at $E_T \simeq 30$ GeV. Differences in the clustering algorithm, tower energy calculation, and tower energy corrections between Level-2 and offline contribute to the trigger inefficiency. A similar study with consistent conclusions was presented in Ref. [7].

4.2 Summary

The trigger efficiency at Level-2 is E_T dependent as a result of the tower clustering algorithm, tower energy calculation and corrections. It reaches up to 100% at $E_T \simeq 30$ GeV. The calorimeter trigger efficiency at Level-1 is essentially 100% and the Level-3 efficiency reaches up to 100% at $E_T \simeq 23$ GeV for the high-E_T electron sample [6]. Again, the end-user should calculate the convolution of the physics sample's E_T distribution with the calorimeter efficiency curve. For $t\bar{t}$ signal events, the Level-2 calorimeter efficiency is calculated to be 0.9966 ± 0.0065 and 0.9963 ± 0.0066 for non-silicon and silicon good run lists. and the Level-3 calorimeter efficiency is $0.9994^{+0.0004}_{-0.0020}$ from Ref. [6].

5 Conclusions

We have presented measurements of the trigger efficiencies for the high E_T electron path, `ELECTRON_CENTRAL_18`, from high E_T electron sample. They are summarized in Table 20 and 21 for electrons passing the "baseline cuts". The differences are a result of the changes in the `XFT` track requirements and Level-3 tracking algorithms.

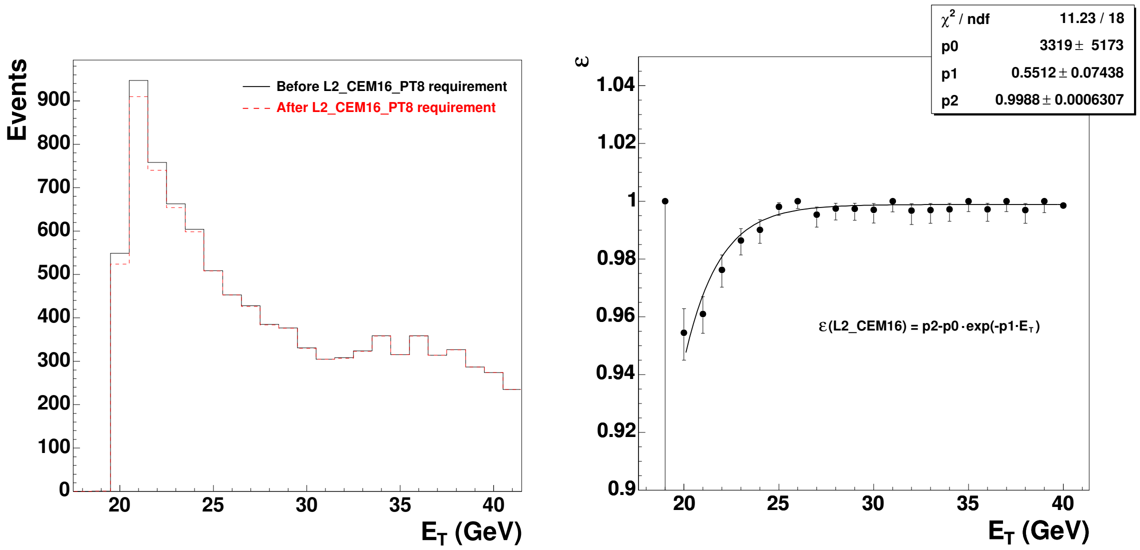


Figure 25: Sample E_T distribution of electron candidates passing the L2_PS50_L1_CEM8_PT8 trigger and the "baseline cuts" (top) and L2_CEM16 trigger efficiency as a function of E_T of electron candidates (bottom) without silicon good run list. These electrons have an isolation requirement such that Isol$/p_T < 0.1$.

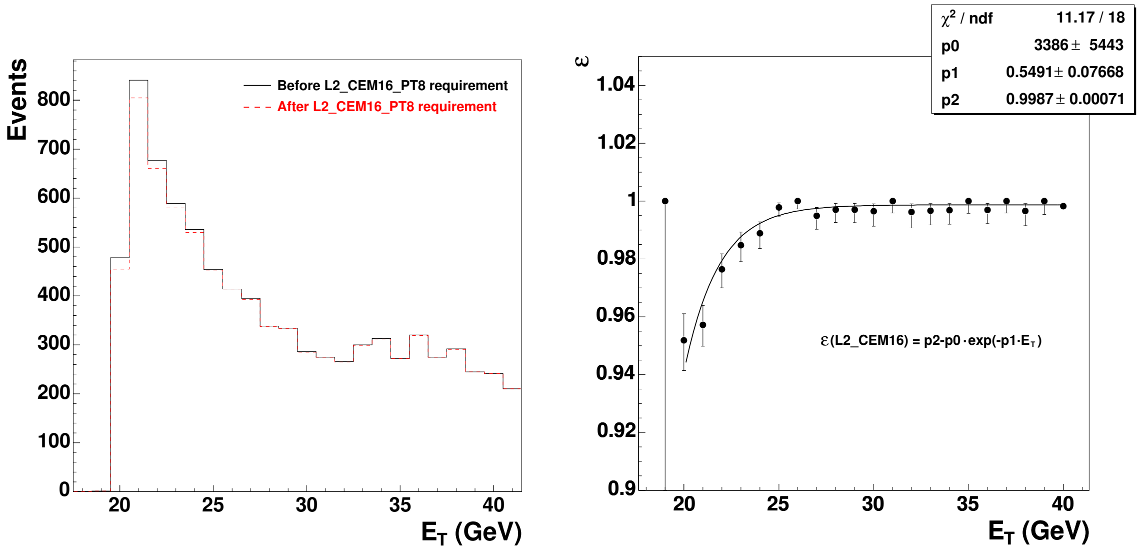


Figure 26: Sample E_T distribution of electron candidates passing the L2_PS50_L1_CEM8_PT8 trigger and the "baseline cuts" (top) and L2_CEM16 trigger efficiency as a function of E_T of electron candidates (bottom) with silicon good run list. These electrons have an isolation requirement such that Isol$/p_T < 0.1$.

Table 20: The summary of electron trigger efficiencies without silicon good run list for various time periods (see section 2) for electrons with $E_T > 20$ GeV.

Trigger	Efficiency			
L1_CEM8	$> 99.9\%$			
L2_CEM16	$0.9988 - 3319.0 \cdot \exp[-0.5512 \cdot E_T]$ (Isolation Ratio < 0.1)			
L3_CEM18	$1 - 2.784 \times \exp[-1.749 \cdot (E_T - 17.86)]$			
	Period 1	Period 2	Period 3	Period 4
L1 XFT PT8	0.9680(23)	0.9875(10)	0.9699(11)	0.9639(11)
L2 XFT PT8	0.9985(6)	0.9991(3)	0.9989(2)	0.9989(2)
L3 Tracking	0.9961(9)	0.9916(8)	0.9928(5)	0.9986(2)
Total Track Trigger	0.9628(25)	0.9783(13)	0.9619(12)	0.9615(12)
	Period 5	Period 6	Period 7	Period 8
L1 XFT PT8	0.9607(11)	0.9638(10)	0.9789(15)	0.9822(7)
L2 XFT PT8	0.9989(2)	0.9985(2)	0.9988(3)	0.9991(1)
L3 Tracking	0.9982(3)	0.9983(2)	0.9975(5)	0.9972(2)
Total Track Trigger	0.9579(12)	0.9606(11)	0.9653(16)	0.9785(7)

[1] The η dependence of these triggers for each of the time periods has been measured. We measure the Level-2 track trigger efficiency to be $(99.89 \pm 0.01)\%$. The Level-2 calorimeter trigger is E_T dependent. The efficiency reaches up to 100% at $E_T \simeq 30$ GeV.

In principle, the electron trigger efficiency for a particular physics process can be calculated by convoluting these results with the electron E_T distribution and with the luminosity distribution as a function of run period. For example, the top analysis which use the electron + $\geq$ 3-jet selection for data with non-silicon and silicon good run list would use 0.9966 ± 0.0065 and 0.9963 ± 0.0066 for the `L2_CEM16` calorimeter trigger efficiency without and with silicon good run list and $0.9994^{+0.0004}_{-0.0020}$ for the `L3_CEM18` calorimeter trigger efficiency [6]. This results in an overall electron trigger efficiency of $0.9620^{+0.0063}_{-0.0066}$ and $0.9617^{+0.0064}_{-0.0067}$ for non-silicon and silicon good run list in the analysis which requires electron $E_T > 20$ GeV.

References

[1] Richard Hughes, Evelyn Thomson, Brian Winer, "Performance Study of the eXtremely Fast Tracker in High Luminosity," CDF Note 5986.

[2] `http://www-cdf.fnal.gov/internal/upgrades/cot/index.html`

[3] `http://www-cdf.fnal.gov/internal/dqm/goodrun/good.html`

[1]The exact definitions of the time periods are described in section 2.

Table 21: The summary of electron trigger efficiencies with silicon good run list for various time periods (see section 2) for electrons with $E_T > 20$ GeV.

Trigger	Efficiency			
L1_CEM8	$> 99.9\%$			
L2_CEM16	$0.9987 - 3386.0 \cdot \exp[-0.5491 \cdot E_T]$ (Isolation Ratio < 0.1)			
L3_CEM18	$1 - 2.784 \times \exp[-1.749 \cdot (E_T - 17.86)]$			
	Period 1	Period 2	Period 3	Period 4
L1 XFT PT8	0.9701(32)	0.9872(11)	0.9687(12)	0.9636(11)
L2 XFT PT8	0.9979(10)	0.9991(3)	0.9989(2)	0.9990(2)
L3 Tracking	0.9969(12)	0.9918(9)	0.9927(6)	0.9986(2)
Total Track Trigger	0.9651(35)	0.9782(14)	0.9606(13)	0.9612(12)
	Period 5	Period 6	Period 7	Period 8
L1 XFT PT8	0.9607(11)	0.9641(11)	0.9784(16)	0.9821(7)
L2 XFT PT8	0.9989(2)	0.9985(2)	0.9988(4)	0.9991(1)
L3 Tracking	0.9982(3)	0.9984(3)	0.9974(5)	0.9972(3)
Total Track Trigger	0.9579(12)	0.9611(11)	0.9646(17)	0.9785(7)

[4] Julia Thom *et al.*, "Determination of the Run II COT Tracking Efficiency Using the W-No-Track Sample," CDF Note 6866.

[5] Ilsung Cho, Intae Yu and J.C. Yun "Inefficiency caused by Wire Center Supports in COT Tracking." CDF Note 6594.

[6] Jason Nielsen, Lauren Tompkins, Doug Hoffman, Young-Kee Kim and Greg Veramendi, "Trigger Efficiencies for High E_T Electrons" CDF Note 6234.

[7] Heather Ray, Monica Tecchio, Rick J. Tesarek, "Level-2 Electron Trigger Efficiencies for Run II," CDF Note 6098.